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of the

Astronomical Society of India.

EDITED BY C. T. LETTON, ESQ.

VOL. IV.

November 1913 to July 1914.

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The Journal of the Astronomical Society of India.

VOL. IV.] SESSION 1913-1914. [No. 1.

Report of the Meeting of the Society held on Tuesday, 31st October 1913.

THE Annual General Meeting of the Society was held on Friday, the 31st October 1913, in the Imperial Secretariat (Treasury Buildings), at 5 P.M. Mr. W. J. SIMMONS, B.A., F.R.A.S., the President of the Society, was in the chair.

The minutes of proceedings of the last meeting of the Society held on Tuesday, the 24th June 1913, were read and confirmed.

The presents received by the Society since the last meeting were announced and thanks accorded to the donors.

The election of the following two members which was decided upon at the meeting of the Council of the Society held on Friday, the 24th October 1913, was confirmed :—

MR. A. B. CHATWOOD.

MR. G. A. K. HUTTON.

Mr. Hutton, who was present, signed the roll at the invitation of the President.

The Secretary, Mr. C. V. Raman, then read the Report of the Society for the session 1912-13, which was adopted.

The President, Mr. W. J. Simmons, then delivered his address and at its conclusion asked the scrutineers to announce the result of the votings in regard to the election of members of Council for the session 1913-14. This was done, the names being as follows :—

President	...	The Hon'ble Mr. W. A. Lee, F.R.M.S.
Vice-Presidents	...	1. H. H. the Maharaj Rana Bahadur Sir Bhawani Singh, K.C.S.I., F.R.A.S.
		2. W. J. Simmons, Esq., B.A., F.R.A.S.
		3. J. Evershed, Esq., F.R.A.S.
		4. Col. Lennox Conyngham, R.E., F.R.A.S.
Secretaries	...	1. Dr. E. P. Harrison, Ph.D. (*Scientific*).
		2. D. N. Dutt, Esq., M.A. (*Business*).
Members	...	1. J. C. Dutt, Esq., M.A., B.L.
		2. S. C. Ghosh, Esq., M.A.
		3. F. W. Howse, Esq.
		4. Hari Das Das, Esq., B.E.
		5. The Hon'ble Mr. P. C. Lyon, C.S.I., I.C.S.
		6. J. C. Mitra, Esq., M.A., B.L.
		7. Dr. D. N. Mullick, B.A., D.Sc.
		8. L. Demetrius, Esq.
		9. Captain A. M. Urquhart, R.A.
		10. Mrs. Tomkins.

The election was confirmed.

The President.—I am sure that in securing Mr. Lee for our President, we have made a good choice. I would now ask him to come and take the chair.

Mr. Lee then took over the chair as President from Mr. Simmons.

Mr. Lee.—Ladies and Gentlemen, I am indeed very sensible of the honour which you have done me in electing me as your President and I assure you that I appreciate it very highly and look forward with much hope relying upon your help to carry it through. I am sure we have listened with very great pleasure to the address Mr. Simmons has been good enough to give us. I may add that I am very interested in some of the things which he has mentioned in his address and

have given them a good deal of my attention. I think you will join with me in returning a hearty vote of thanks to Mr. Simmons for his address.

A cordial vote of thanks was then aceorded to Mr. Simmons and the meeting was adjourned after the usual vote of thanks to the office bearers for 1912-13, the auditors and the scrutineers.

The Report of the Astronomical Society of India for the year ending 30th September 1913.

The Council beg to submit the following report on the progress and operations of the Astronomical Society of India for the session 1912-13, which ended on 30th September 1913.

2. *Members.*—The Society has completed the third year of its existence. It entered into its third session with 254 members and 21 members were elected during the year, giving a total of 275. Of these 15 members resigned, with effect from the commencement of the session, 1 died, and 50 members were removed under Bye-law 27. The Society had thus 209 members on its roll on the 1st October 1913. The Council greatly regret to have to record this reduction in the numerical strength of the Society, but trust that the defaulting members by prompt compliance with the Bye-law will render this feature of the Report temporary.

3. *Meetings.*—The Council held 9 ordinary meetings for discussing the transactions of the Society. The attendance at these meetings testifies to the interest taken by its members.

Besides these, several meetings of a sub-committee of the Council were held to discuss and arrange the details of the Conversazione at the Town Hall, further reference to which is made below.

The ordinary monthly meetings of the Society were held generally on the last Tuesday of each month from October 1912 to June 1913, and were presided over by the President, except on one occasion when he could not attend and his place was taken up by Col. S. G. Burrard. Several papers on astronomical subjects were read at those meetings and interesting debates were held on them.

4. *Quarters.*—The business of the Society was conducted in a room of the Imperial Secretariat Buildings and the Library is housed in a small room in the same building placed at the disposal of the Society by the Comptroller-General. The gratitude of the Society is due to the Comptroller-General for his kindness.

5. *Library.*—Some additions were made to the Library during the session by purchase, but the principal ac-quisitions were the numerous and valuable presents received by the Society. The Maharaj Rana Bahadur Sir Bhawani Singh, K.C.S.I., F.R.A.S., Professor Joges Chandra Roy, and several others presented books and money to the Society, several valuable presents in the shape of books; memoirs and journals were also received during the session from Societies and Observatories in other countries. The Library has now more than 200 volumes in addition to journals and other periodicals. The thanks of the Society are due to the respective donors who have thus helped to advance the cause of Astronomy in this country.

All possible facilities were given to the members who took out books from the Library.

The reading room of the Library was kept open daily from 5 to 7 P.M. and from 3 to 5 P.M. on Saturdays, except on holidays. The Assistant Librarian is in charge of the books and every facility is afforded to members who attend at the Library to make use of the books of reference and the periodicals and journals which are received from Foreign Societies and Observatories.

6. *Instruments.*—During the current session two observatories have come into existence in which active observational work is being prosecuted by members of the Society, the results of which it is hoped will form an asset for the Society's publications. The Revd. Mr. Mitchell's Observatory at Bankura is equipped with a 5″ Cooke equatorially mounted refractor which, judging from the results already published in the Society's Journals, gives a very good performance. A detailed description of the observatory was published in the Journal for February 1913. The Secretary, Mr. C. V. Raman, visited the Mr. Mitchell's Observatory at Bankura in July last and was much impressed with the excellent views of Jupiter given by the instrument.

Towards the end of the session a 7″ equatorial refractor by Merz with clock-work complete was mounted at Calcutta by the Indian Association for the Cultivation of Science. It is being used by our Secretary, Mr. Raman, for observational work on Jupiter, and it is hoped that a regular programme of work on variable stars will be undertaken during the ensuing session at this observatory. The Council trust other members who possess instruments, however small or large, will come forward and co-operate in the scheme of observational work. A great deal can be done in many directions even with very modest instrumental equipment, and meteor

observations furnish a field which is available to those who do not possess telescopes.

The 4″ reflecting telescope presented by Dr. E. P. Harrison is in the Library and can be used by any member sending an intimation either to the President or the Secretary. It is hoped that it will be regularly used during the coming session.

7. *Society's Publications.*—The Journals of the Society were published as usual during the nine working months of the session. They contain the proceedings of the monthly meetings in full, the astronomical papers read at those meetings as well as extracts from important publications of a similar kind. Several interesting photographs were also reproduced therein.

A volume containing reprints of the three public lectures delivered during the session 1911-12 by Col. S. G. Burrard, Mr. H. G. Tomkins, and Dr. E. P. Harrison was also published and distributed free to members.

8. *Recognition of the Society.*—The following Societies and Observatories regularly sent in their publications in exchange for the Society's :—

1. Royal Astronomical Society, London.
2. British Astronomical Association, London.
3. Royal Astronomical Society of Canada.
4. Astronomical Society of Italy.
5. Astronomical Society of Barcelona.
6. Royal Observatory of Scotland.
7. Vatican Observatory.
8. Astronomer Royal, Greenwich.
9. Royal Observatory of Belgium.
10. Director of Indian Observatories, Alipore.
11. Director of Kodaikanal Observatory.
12. Oxford University Observatory.
13. Radcliffe Observatory.
14. Astronomical Society of Leeds.
15. Paris Observatory.

The special thanks of the Society are due to Mr. Evershed, Director of the Kodaikanal Observatory, for the assistance he has accorded in lending valuable slides from time to time for the meetings with his notes thereon.

The Journal of the Society is subscribed to by the authorities of the following Colleges :—

1. The Presidency College, Calcutta.
2. The Sanskrit College, Calcutta.
3. The Hooghly College, Chinsurah.
4. The Krishnagar College.

5. The Patna College.
6. The Muir Central College, Allahabad.
7. The Elphinstone College, Bombay.

9. *Steps taken to popularise the Society.*—With a view to popularise the Society the Council decided that the following work should be taken up by the Society during the year :—

(*a*) Public lectures in Calcutta.
(*b*) Correspondence classes for members who were beginners.
(*c*) A Conversazione at the Town Hall.

During the session three public lectures were delivered at Calcutta, under the auspices of the Society. The first lecture was delivered by the Hon'ble Mr. W. A. Lee on the 15th January 1913, his subject being "The Life History of a World." The Chairman on the occasion was the Hon'ble Sir F. W. Duke. The second lecture was on "The Sun," and was delivered on the 17th February 1913 by Dr. D. N. Mullick, D. Sc., F.R.S.E., with the Hon'ble Sir Richard Harington as Chairman. The third lecture was delivered on the 21st February 1913 by the Revd. J. Mitchell, M.A., F.R.A.S., his subject being "Comets"; Justice Sir Ashutosh Mookerjee was in the chair. All these lectures were very largely attended by the public, who seemed to take great interest in them.

(*a*) The lectures were delivered at the Town Hall, Calcutta, which was kindly placed at the disposal of the Society free of charge by the Calcutta Municipal Corporation, to whom the gratitude of the Society is due.

(*b*) The correspondence classes in Astronomy conducted by the Director, Mr. H. G. Tomkins, were taken advantage of by a large number of members and formed a special feature of the working of the session year. It is hoped to continue them during the current year.

(*c*) A Conversazione was held at the Town Hall on the 29th January 1913, where a collection of drawings, photographs, instruments and other objects of interest was put up. A detailed account of it appeared in the issue of the Journal for February 1913. The function proved a great attraction and was an unqualified success. The expenses of the Conversazione were met from special donations given by the President and members of the Council. A list of the donations paid is appended to the accounts.

10. The accounts of the Society for the year under report are shown in the accompanying statements.

I. Revenue Account, Session 1912-13.

I. General Revenue Account for Session 1912-13.

EXPENDITURE.	Rs.	A.	P.	RECEIPTS.	Rs.	A.	P.	Rs.	A.	P.
To Establishment	272	12	0	By Subscription— 254 members on 1-10-12 @ Rs. 8 ...	2,032	0	0			
,, Postage and Telegram charges	155	12	0	*Add*—New members— 26 @ Rs. 8	208	0	0			
,, Office Expenses and Miscellaneous... ...	82	15	3	4 @ Rs. 4	16	0	0			
,, Discount for cashing cheques	1	10	6	*Deduct*— 50 members struck off @ Rs. 8 ... ... 400 0 0	2,256	0	0			
,, Typing charges	8	0	0	15 resigned @ Rs. 8 ... 120 0 0						
,, Printing charges :— Cost of printing Journals	1,001	2	0	1 dead @ Rs. 8 8 0 0						
,, Cost of miscellaneous printing	160	11	0	8 new members @ Rs. 8 and 1 @ Rs. 4 not paying anything during 1912-13 ... ... 68 0 0	596	0	0			
,, Cost of a Port Trust Debenture transferred to Capital Account	104	3	6		1,660	0	0			
,, Depreciation in the stock of Library Books ...	25	4	10	Amount realised for Session 1911-12— 156 @ Rs. 8 ... = 1,248 0 0						
,, Depreciation in furniture	14	2	4	10 @ Rs. 4 ... = 40 0 0						
,, Depreciation in telescope	7	8	0	1 @ Rs. 3 ... = 3 0 0	1,291	0	0			
				Deduct—Amount realised in 1911-12 ...	39	0	0	1,252	0	0
				Amount in arrears— (50 names struck off, 15 resigned, 1 dead)						
				42 @ Rs. 8 ... ... =	336	0	0			
				7 @ Rs. 4 ... ... =	28	0	0			
				1 new @ Rs. 5 ... ... =	5	0	0			
					(*a*) 369	0	0			
	1,834	1	5							

Amount written off Suspense Account by debit to Revenue Account :—	Rs.	A.	P.				
Subscription ...	377	0	0				
Entrance Fee ...	8	0	0				
				385	0	0	
				2,219	1	5	
Add—Closing balance				364	9	3	
Total ...				2,583	10	8	

Subscriptions realised in advance for 1913-14 and future year—						
3 @ Rs. 8 ... ... =	24	0	0			
1 Lump Life Member ... ... =	84	0	0			
				108	0	0
By Entrance Fee amount due—						
30 @ Rs. 4	120	0	0			
Deduct—8 @ Rs. 4 new members not paying anything during 1912-13 ...	32	0	0			
				88	0	0
Realised in Session 1912-13—						
22 @ Rs. 4	88	0	0			
By sale of Journals				62	4	0
,, Advertisements				59	10	0
,, Miscellaneous				6	0	0
,, Interest on debenture				1	15	2
,, Donation				150	0	0
Actual Receipts ...				1,727	13	2
Add—Unrealised subscriptions as (*a*) by debit to Suspense Account				369	0	0
Add—Unrealised advertisement due from Messrs. Clarkson & Co. for 1912-13 by debit to Suspense Account				30	0	0
				2,126	13	2
Add—Opening balance of Revenue Account for 1911-12				456	13	6
Total ...				2,583	10	8

U. L. BANERJEE,
Treasurer.

II. General Balance Sheet on 30th Sept. 1913 as modified.

Liabilities.	Rs. A. P.	Rs. A. P.	Assets.	Rs. A. P.	Rs. A. P.
Sundry Creditors			*Capital Account*—		
			P. T. Debenture for Rs. 100 ...		100 0 0
			Library Stock of Books 503 11 0		
			Additions in 1912-13 3 4 0		
			506 15 0		
			Deduct—5% depreciation charged to Revenue Account 25 4 10		
					481 10 2
Revenue Account—			Value of Telescope (as assessed by the Director of Instruments) 150 0 0		
Balance of Revenue Account ...	364 9 3		*Deduct*—5% charged to Revenue Account 7 8 0		
					142 8 0
Library Account—					
Balance of Library Account ...	58 5 5		*Furniture*—		
			Last year 141 7 7		
Deposit Account—			*Deduct*—10% depreciation charged to Revenue Account 14 2 4		
Balance of Deposit Account ...	181 6 6				127 5 3
			Unsold Journals—		
			1910-11 ... 1,942		
			1911-12 ... 2,122		
			1912-13 ... 2,700		
			6,764		
			@ As. 2 per copy ...		845 8 0
			Sundry Drs.—		
	604 5 2		(Unrealised assets as per Suspense Account 1912-13)—		
			Subscription for 1911-12 ...		8 0 0
			Subscription for 1912-13 ...		369 0 0
			Advertisement ...		30 0 0
			Cash Balance in the Alliance Bank of Simla, Ld. ...		298 4 7
Excess of Assets over Liabilities ...	1,824 0 7		Cash with Treasurer		26 10 9
	2,428 14 9				2,428 14 9

U. L. BANERJEE,
Treasurer.

The President's Address.

OCTOBER 1913.

Widespread and time-honoured custom requires the President of such a Society as ours to utilize the Annual General Meeting as an occasion for reviewing the work of the year preceding it, and offering such remarks and suggestions thereon as may in his opinion be conducive to improve methods and results in the year to come. He is also required to notice in some degree the work which has been done elsewhere in connection with the branch of Science to which the Society devotes its efforts. And finally he is supposed to bring before the meeting his views on whatever particular subject may interest him personally. I shall endeavour to follow accepted precedent in these respects.

You have heard the Secretary's Report, and although it refers to a falling off in membership, and bears some traces of the chronic complaint which afflicts all Societies and Institutions in this great city, I shall not take a pessimistic view of our position. It was inevitable in establishing the first Astronomical Society in Calcutta that sundry persons would join it at the outset, who would discover in no long time that the Society did not come up to their expectations, nor meet their requirements. I trust that though a goodly number of such persons have fallen out of our ranks, those of us who still remain together will be able to work on successfully and usefully. In a city like Calcutta where owing to climatic, business and social reasons, one's energies must in the first instance be directed to the stern work of life, and in the next to the sometimes too earnest quest of "a good time," the mental effort which the pursuit of any branch of Science demands is likely in a large number of cases to prove a severe discipline. I, therefore, am not too despondent because we start on the new session with only 209 members on our Roll instead of 275. Where the falling off in membership affects us most seriously is of course from the financial point of view.

The average attendance at our meetings during the past session was about 16, a number which I who have had some experience in the working of Calcutta Societies, do not consider discouraging. It might have been larger. Visitors were present at 7 of our meetings, the largest number of visitors present at any one meeting was only 4. Under our rules, members are entitled to introduce two visitors each; I think it would be well if they more frequently availed themselves of their right to do so. I think if we had had

more visitors at some of our meetings, we would have closed with more than 209 members on our Rolls. In calling your attention to this feature I venture to submit that the Society would be better and more legitimately advertised than it can be by other methods which might be named, and that all our members can serve the interests of the Society by endeavouring to increase our membership by bringing the Society to the notice of their friends in the way I suggest. Then, again, members themselves should in my opinion keep the last Tuesday of each month free from other engagements. We should try to bear in mind that those who take the trouble to prepare papers (often illustrated) to be read at our meetings have to put their backs into their work, and it is at least discouraging to come here, and read such papers to so many empty chairs. Further, members who attend our meetings would materially help to advance our work if they more frequently joined in the discussions which follow the reading of the papers. We all know each other fairly well by this time, and there is no need to be afraid to hear ourselves speak, or to let our friends hear us do so. Take my advice then, and join more than you do in our discussions. I would beg of members to accept my remarks in as kindly a spirit as I offer them, when I further ask you to look up a subject which is coming on for discussion at a meeting, in such books as are available to you, because it is quite probable that you may thus be able to direct attention to some point which the author of the paper may himself have missed. A little previous preparation would suffice to at least enable you to point out where a given theme can be linked on to other branches of Science, and this would in itself be a useful contribution to the work of the meeting. I should not pass on from this portion of my address without special reference to the series of papers which Mr. Tomkins prepared on "The Construction of a Cheap Telescope." They were a great help to your Council in framing the Agenda papers for our meetings during the past sessions; and our special thanks are due to the founder of our Society for what he did in this direction. Another feature in our meetings during that session has been the interest which was aroused by papers dealing with the ascertainment of the dates of historical events by references in the literature of Ancient India to the positions of the planets and the stars. It was this feature I had in view when I mentioned the need for a little previous preparation as an equipment for the profitable discussion of the papers brought before our meetings. Although a vote of thanks was recorded to each of the members who read papers at our meetings during the last session,

it is fitting that as President I should here tender to them my own personal thanks for the help they have given us, and for the trouble they have taken in aiding us in carrying out the objects of the Society.

This leads me in the next place to observe that members would do well to make more use of our Library. It is a growing adjunct to the Society. It includes several valuable and instructive volumes, and there are many worse ways of spending an occasional hour in the early evening than by looking in at the Library, and quietly conning over some book which you find there. As your Report has correctly stated, every facility is given to the members who go to the Library to make use of the books in it.

The financial position of every Society which has not the advantage of being endowed, is necessarily dependent on the funds subscribed by its members, as members, and such subscriptions ought to be its only source of revenue. Our Society has to maintain a Journal the printing of which is our chief item of expenditure. The Journal ought to be maintained, and I trust that all our members will in future bear these facts in mind. Your Council as appears from the Report which has been read to you has had in the discharge of its duties to remove the names of 50 persons from the Roll of members, under Bye-law 27. I trust the Council about to enter into office will have fewer defaulters to deal with.

Turning from ourselves to the progress of Astronomy elsewhere, it is interesting to note that no less than 79 new planets were discovered, or first announced, in 1912, and several of these during the period covered by our Report. The year has been a poor one in comets. We had 8 in 1911. We have had only about half a dozen since. The relationship between Halley's Comet and the Meteors (the Aquarids) which have their radiant near Eta of Aquarius in the month of May, was suggested as probable by Professor A. S. Herschell, and seems now to be well established. These meteors which were discovered in 1870 by Col. Tupman, are strong brilliant meteors, and move in fine, long paths. They should be looked for in the last days of April and early in May. Aquarius which while I speak to you is near the meridian, will at that season of the year be visible in the eastern sky about 4 o'clock in the morning. They may also be looked for about three months later, *viz.*, on the 28th July ; but it is only the May shower that is associated with Halley's Comet.

As regards solar activity we appear to have entered upon a new cycle. In the year 1911 there were 186 days without

sun-spots: in 1912 there were as many as 250 such days: in 1911 the number of separate groups of spots observed was 62: in 1912 there were only 33. The marked decrease in solar activity continued through November and December 1911, and January and February 1912; the decline is considered exceptionally rapid, and the most abrupt that has occurred since 1833. The decline in faculæ and prominences was also very marked. In March of last year an interesting group came into view, which, however, faded, but later on two new spot groups appeared—the second of which developed into a fine stream visible at the end of April. In May 1912 eight small groups were visible—the largest number for a whole year. Two returned in June, and the increase has been since maintained. It is, therefore, probable that 1911-12 was the actual year of minimum sun-spots. Those who take an interest in such statistics will be pleased to know it is said that there is an increase in the number of marriages in the years of maximum solar activity. The observation has nothing whatever to do with Astrology! I would here note in connection with Solar Physics that the entire equipment of the Poona Observatory was during 1912 transferred to Kodaikanal, and several re-arrangements and adaptations of instruments were made which occupied a great deal of time; and it is noteworthy that the usual routine work of the observatory was scarcely interrupted. Direct photographs of the sun on a scale of 8 inches to the diameter, some of which were probably amongst the slides sent to us, and exhibited in this room, were taken at Kodaikanal on 329 days. Monochromatic photographs of the Sun's disc in "K" light were taken on 331 days, and prominence plates on 280. The general state of calm in the solar atmosphere, which was not favourable for the study of radial movements, was specially so for other lines of solar research. Three solar, and two lunar, eclipses make up the record for 1913, and there have been two occultations of Spica by the Moon—one on the 28th January and the other on the 23rd March.

On the 12th March 1912 a Nova was discovered in Gemini which was made the subject of some interesting observations in spectrum analysis, and Dr. Kustner found radium emanations in the spectrum of this Nova. Prolonged exposures at the Tatsfield Observatory on the fainter portions of the Great Nebula in Orion in the neighbourhood of the *iota* group have established the existence of extensions of the nebula which appear to have escaped previous observation; and have also disclosed a large, faint nebula, but the absence of dry, dark nights prevented the completion of these observations.

It is usual as already suggested for the President on such an occasion as the present to bring forward some remarks of his own on any subject in which he has himself taken an interest during the period under review. For such remarks he, and not the Society, is responsible. The question of life in other worlds than ours has always been of some interest to myself, though I am bound to add that the more I think about it the less hopeful do I become of our arriving at a satisfactory solution of the problems presented for consideration. That we shall one day be in a better position to suggest answers to the questions which arise is I feel certain: but not yet! You will remember that as far back as the 30th April 1912 I read a paper in this room entitled "The Habitability of the Planets and the apparent waste in Nature." That paper had special reference to the habitability of Mars, and was inspired by a then recent perusul of Professor Lowell's "Mars as the abode of Life," and Mr. Alfred Russel Wallace's "Is Mars Habitable"? In the course of the remarks I then made I directed attention to the use of the argument from analogy in the investigation of the problems raised by my thesis. It was my intention to follow up that paper with one directed to certain facts which should make us cautious in assuming that if intelligent life exists, on say Mars, that planet must be inhabited by beings to which psychical attributes identical in kind and degree with those of full fledged humanity should be assigned. The claims made on behalf of the existence of life in Mars are a challenge to every educated man to investigate for himself the evidence adduced. Here I would specially warn you against the trap into which we are only too prone to fall if we use the argument from analogy too freely, and without due regard to researches based on observation, in departments of scientific investigation widely removed from Astronomy, but which assume a profound degree of importance for the astronomer as soon as he begins to speculate on the origin of life, or on the possibility of the existence of intelligent life in other worlds. David Hume, in one of his essays which has exercised some influence on modern thought, says:—"There is an universal tendency among mankind to conceive all beings like themselves, and to transfer to every object those qualities with which they are familiarly acquainted, and of which they are intimately conscious." And further on "philosophers cannot entirely exempt themselves from this natural frailty; but have often ascribed to inanimate matter the horror of a vacuum, sympathies, antipathies and other affections of human nature. * * * * * The unknown causes which continually employ

their thought, appearing always in the same aspect, are all apprehended to be of the same kind or species. Nor is it long before we ascribe to them thought, and reason, and passion, and sometimes even the limbs and figures of men, in order to bring them nearer to a resemblance with ourselves." (Hume's Natural History of Religion, Section II, p. 520.) Ragozin in the 5th edition of his "Story of Chaldea," referring to the faculty described by Hume in my previous quotation, says :—"This tendency is so universal, that it has been classed under a special name, among the distinctive features of the human mind. It has been called Anthropomorphism (from two Greek words, *Anthropos*, 'man,' and *Morphe*, 'form'), and can never be got rid of because it is part and parcel of our very nature." Like caste, like animism, like polytheism, like slavery, like the Village Community, anthropomorphism has been, and still is useful, in certain stages of culture. It lies at the very beginning of our consciousness ; it only becomes a menace when owing to advancing civilization it survives the period of its beneficial activity, and threatens to be an obstacle to further advancement. It has been said of anthropomorphism that from the point of view of Science it is the Seventh, and deadliest of sins : "we are egocentric, egoprojective" (Darwin and Modern Science, p. 508). Herbert Spencer in an essay on "The Use of Anthropomorphism" has shown that "even in its crudest and grossest forms it has had its relative justification, since it has played an important part in the higher development of the race." (Hudson's Introduction to the Philosophy of Herbert Spencer, p. 105). From a sociological point of view it prepares the way for milder discipline.

I am quite aware that in applying the term "anthropomorphism" to the attribution of a more or less manlike form, and especially of human psychical faculties to the hypothetical inhabitants of Mars, or any other planet, I depart somewhat from the strict use of the word by the very authorities I have cited. They use it exclusively in reference to manlike conceptions of God, or the gods, whereas I have applied it in a far wider sense as indicating the principle according to which man interprets all things through himself. I, however, am unable to recall any other term which better expresses my meaning ; and with this explanation I pass on to observe that in applying analogical methods to the consideration of the conditions observed to obtain in Mars, or any other planet concerned, in so far as they may be suggestive of the existence of life in such planets it is necessary to go altogether outside of Astronomy proper, and to trench on the domain of Biology. It is impossible to deal with the

problems which arise in any other way. The analogies to be adduced must be drawn from fields of enquiry which the biologist rather than the physicist, or the mathematician, or the astronomer, has worked out. Indeed if the argument is to approach in strength anywhere near to a valid induction, analogies must be sought in every domain of science.

These remarks are introductory to my directing your attention to a series of observed facts the significance of which will be best appreciated by those who glancing aside from the starry heavens themselves, have bestowed some attention on the psychical phenomena exhibited by animal organisms to which by common consent a lower rank is assigned in the scale of intelligence than is claimed for man, whether it be in respect to his mental or his moral characteristics. You will remember that in my previous paper I told you that in order to support the claim that types of life approximating to the human exist in Mars, or in Venus, "indicia" which with reason can be claimed to be artificial, in a word, which are evidences of "intelligent engineering upon a gigantic scale" must be shown to exist in our neighbouring planets. Mr. Percival Lowell claims to have found such "indicia" in Mars. Accepting for the nonce the validity of his claim, can we stop short at nothing below *homo sapiens*—or must we even go beyond him ?—to account for them ? Are there any analogies available which, however faint they be, may not be without value in suggesting observations, and laying trains of thought that may lead to positive conclusions ? Obviously non-natural, that is artifical contrivances such as are claimed to have been found in the Martian "Canals," point in the first place to a remarkable degree of foresight; they also indicate ability to adapt means to a common, and a concerted end; in other words, they connote a high degree of intelligent co-operation. Can it be maintained that foresight, and the ability to adapt means to a common and a concerted end, and intelligent co-operation are restricted to man ? He no doubt possesses these qualities in a markedly high degree; but the lowly beginnings of every one of his psychic faculties have their germinal roots in lower forms of life. The difficulties he has had to contend against, and to surmount in his environment in this planet, have given him his supremacy in this direction, just as in the struggle for existence against factors in his environment, he has obtained his erect attitude, his opposable thumb, and those other faculties which have secured him the lordship over the lower races. In a different environment other faculties and features would assuredly have been developed, just as on our own planet in the surroundings of the coal measures,

we know that physical forms of life, widely differing from those which now prevail, were developed, and lived, fought each other, and died out, with the environment in which they were evolved. The Martian conditions are not identical, —are we at liberty to assume they ever were identical ?— with those obtaining on our Earth; and therefore even if they have eventuated in some degree of intelligent life, they need not have eventuated precisely in man. And here it may be well to remind you that it has been said wherever there is life there is some degree of intelligence, in other words, that all life is sentient life; and that, therefore, the plastic matter of life is enabled to adapt itself to its environment,—a proposition which (if accepted) at once implies a conscious element in the struggle for existence, and the survival of the fittest, not necessarily the fittest from a moral point of view, but simply the fittest to maintain a foothold in a given environment.

Do not say all this is out of place on the present occasion as it pertains to biological rather than to astronomical science. When once you as astronomers begin to speculate on the habitability of the planets, you can no more avoid Biology than you can avoid Chemistry when the Spectroscope has revealed the existence of certain terrestrial elements in our Sun, or in Sirius, or in some transient star which flashes its light on us for a brief season, from the outskirts of the visible universe, as the Nova in Gemini did recently. Now what inspires the most advanced of human communities to project, and to execute great engineering works like the Suez Canal, and the Panama Canal, obviously is at bottom of this very struggle for existence on which I lay so much stress, and which is essentially a strenuous effort to establish individual, or racial, or national, supremacy: briefly, to maintain a foothold. Let us, then, enquire if amongst organic beings now inhabiting our own planet the exhibition of intelligent co-operation, and the ability to adapt means to effect a common and concerted end, and to surmount natural obstacles present in the environment, is restricted to man ? We have at once to admit that there are organisms with which we are not unfamiliar, and which are exceeding wise. The locusts have no king, yet go they forth all of them by bands. The conies are but a feeble folk, yet make they their houses in the rock. The ants are a people not strong, yet they provide their meat in the summer, and gather their food in the harvest. All this connotes co-operation. The co-operative labours of the ant moreover extend beyond harvesting operations; they are known to include the making of slaves; the waging of

war and dairy keeping; and a colony of ants includes architects, builders, carpenters, sappers and helpers. Many other instances of the division of labour amongst these insects might be given with reference to their sense of direction, their powers of memory and of communication, their emotions, their wars, their funeral habits, their ability to adapt themselves to circumstances, and other faculties which point rather to purposive intelligence than to what we are pleased to term merely blind and purposeless instinct. (See Romanes Animal Intelligence, p. 31—142; Darwin's Descent of Man, p. 227). Passing on from ants to bees, yet other examples present themselves for consideration in the study of the social life of organisms below man in the psychic scale. I need only remind you of the often quoted skill of bees in the construction of their hexagonal cells, and of their wars obviously waged for the purpose of securing plunder; while the high order of intelligence which they exhibit in their civic, or communal, sanitary arrangements furnishes precedents which man himself might, in certain backward phases of his civilization, do well to follow (Darwin's Descent of Man, p. 151; Romanes Animal Intelligence, Ch. IV, p. 145, etc.; Darwin's Origin of Species, p. 342).

Those who consider that our Civilization will attain its zenith-point only when our social institutions have assumed a communistic and socialistic type, need to be reminded that we have already been anticipated in this direction by certain lower organisms—organisms which already base their communal life on a foundation suggestive of the goal to which certain modern politicians and sociologists would lead us. Professor Forel (Sexual Ethics, p. 24) says:—"The necessity of protection against common foes brought about in the case of many animals a ripening of the sense of sympathy, and it became extended to whole groups, so that here and there free communities (swallows, buffaloes, monkeys) have resulted. Finally certain species have developed the senses of sympathy and duty to such an extent that they have led to a complete anarchistic Socialism, as is the case among wasps, bees and ants. Here the social sense has so far overcome both egotism and altruism limited to a few individuals that it wholly dominates them. The individual devotes his whole energy and labour to the communal existence, and even sacrifices his life for this object." Dr. Mercier (Crime and Insanity, p. 29) says:—"We see in communities of social insects, the complete subordination of the racial and self-regarding instincts to the social instincts. Every hive of bees, every nest of wasps

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war and dairy keeping; and a colony of ants includes architects, builders, carpenters, sappers and helpers. Many other instances of the division of labour amongst these insects might be given with reference to their sense of direction, their powers of memory and of communication, their emotions, their wars, their funeral habits, their ability to adapt themselves to circumstances, and other faculties which point rather to purposive intelligence than to what we are pleased to term merely blind and purposeless instinct. (See Romanes Animal Intelligence, p. 31—142; Darwin's Descent of Man, p. 227). Passing on from ants to bees, yet other examples present themselves for consideration in the study of the social life of organisms below man in the psychic scale. I need only remind you of the often quoted skill of bees in the construction of their hexagonal cells, and of their wars obviously waged for the purpose of securing plunder; while the high order of intelligence which they exhibit in their civic, or communal, sanitary arrangements furnishes precedents which man himself might, in certain backward phases of his civilization, do well to follow (Darwin's Descent of Man, p. 151; Romanes Animal Intelligence, Ch. IV, p. 145, etc.; Darwin's Origin of Species, p. 342).

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or ants, is a crimeless community. It is free from crime, not because of the severity of its criminal law, or of the vigilance of its police, but because the instinctive desires of its members have been brought into complete harmony with its social welfare. * * * * * * *
Except in consuming food enough to keep itself in vigorous bodily health the whole of the energies of every member of the community are devoted to securing, not its own welfare, but that of society at large. All the property goes into a common fund. No individual appropriates to itself anything beyond the food she consumes; or hesitates for an instant to sacrifice her life, or the lives of her brothers, for the benefit of the community. * * *
* * * * Bees, ants and wasps are in fact perfectly socialized. Their instinctive desires are brought into complete harmony with the needs of the social state and consequently they are crimeless; for this is the condition, and the only condition under which crime disappears from want of motive to perpetrate it." In our speculations on life in other worlds we must then be more disinterested, and less self-centred than we are! "It is not hard," says Professor Marett (Anthropology, p. 18), "to be candid about bees and ants; unless indeed one is making a parable of them. But (as scientists) we must try what is so much harder, to be candid about ourselves." The researches made on these subjects possess great interest, but I must content myself by referring you to Romanes' book on Animal Intelligence (p. 143—197) for details.

Let me next notice all too briefly an animal which is conspicuous among social animals, not only for its instinct, but also for its intelligence. I refer to the beaver. "There is no animal," says Romanes, "not even excepting the ants and bees, where instinct has risen to a higher level of far-reaching adaptation to certain constant conditions of environment, or where faculties undoubtedly instinctive are more puzzlingly wrought up with faculties no less undoubtedly intelligent. So much is this the case that as we shall presently see it is really impossible by the closest study of the psychology of this animal to distinguish the web of instinct from the woof of intelligence; the two principles seem here to have been so intimately woven together, that in the result, as expressed by certain particular actions, it cannot be determined how much we are to attribute to mechanical impulse, and how much to reasoned purpose." That mere blind instinct can explain or account for all that is worked out by a colony of beavers, is met by the fact that these animals vary the mode of construction of their lodges in accordance with

changes of situation. In selecting the site of these lodges they display a high degree of sagacity and forethought; they too like the social insects procure and store food; they construct dams with the only too obvious object of forming artificial ponds, each dam being carefully adapted to the special locality in which it is built; on a scale, which it may be conceded is limited, they almost seem to emulate the engineering feats claimed for the hypothetical inhabitants of Mars, inasmuch as—and I would ask your special attention to this—they too excavate canals which are not only many hundreds of feet long, but in the construction of which they display what can only be rightly termed forethought in engineering details. Beavers know how to apply to advantage the principle of locks combined with collecting reservoirs similar to those used in canals of human construction. Their burrows have ventilation pipes; where they meet with the loop of a river, they make a short-cut waterway, across the ground, and thus shorten for themselves the distance of transport. The perseverance with which they work out their concerted designs is no less noteworthy. Romanes, citing the authority of observers who made these rodents a special study, tells us they change the whole aspect of enormous tracts of country, covering with water great areas which were once thickly wooded, and working persistently for hundreds, if not thousands, of years. Agaziz secured evidence of an existing beaver dam which he estimated must have been a thousand years old. Is it to be wondered at that the North American Indians believe the beaver is gifted with immortality? (Romanes' Animal Intelligence, p. 367—385. See also Darwin's Descent of Man, p. 101, 104 and notes. Also *Art.* "Beaver" in Chamber's Encyclopedia, Vol. II, p. 4, edition of 1908.)

Numerous other instances of animal intelligence are available in books devoted to this branch of natural science, and it is to their pages that I must refer any who would seek for fuller information. (See, *inter alia*, Darwin and Modern Science, p. 121, 429—431, 263—269; Romanes' Animal Intelligence, p. 10—17; *Art.* "Instinct." XIV Encyc. Brit., p. 648, etc., 11th Edition; *Art.* "Instinct," VI Chamber's Encyc., p. 174, Edition of 1908).

Let me here guard myself against the imputation—a not improbable one—that I suggest the "Canals" in Mars are the work of beavers. I do not do anything of the sort. I know nothing about the constructors of those "Canals," nor does Mr. Lowell. My one object is to direct your attention to researches which I submit you cannot ignore if you would speculate on the possible habitability of other planets

circling round our Sun. You must sweep into your net all the analogies you can ; you must keep in view what animals psychically lower than man are known to be capable of doing —animals to which we, as I consider all too hastily, and not without some dash of a feeling nearly allied to racial pride, deny the possession of any psychic gift higher than what we contemptuously sneer at as mere animal instinct,—animals to which many unthinkingly, and therefore unreservedly, deny the prerogative of any degree of reason. Once admit that in any world conditions have favoured the evolution of living organisms, and it seems to me impossible to deny the existence amongst them of the formative action of the struggle for existence and the survival of the fittest, and of all that necessarily follows from the operation of those two factors. The whole evolution of life is one vast process of natural education carried out under stringent conditions, far more compulsory, and far more rigidly enforced than any ever imposed by the most case-hardened of officials in the most autocratic of human governments. The direct result of Nature's stern educational system is that such of its pupils as survive its disciplinary rigours are fitted for the discharge of life's duties : those who would disregard her discipline fare exceedingly badly at Nature's hands.

From this point of view it seems to me reasonable to infer that if animal life obtains in Mars, the organisms evolved may, in view of what we know animal intelligence has accomplished in our planet, be able to emulate the achievements of organisms living in communities on our Earth, and this without necessarily having risen to precisely the lofty point of psychic development which we claim for ourselves. All of us will remember reading from time to time reports that certain observers have noticed lights on Mars which indicated that its inhabitants were probably signalling to us, and that we ought to devise some method of responding to their efforts. That luminous areas have been observed is likely enough, and we need not deny the fact. If we saw a new and unusually bright area on the Moon's surface we would probably attribute it to volcanic activity. I, therefore, submit that it rather savours of anthropomorphism to say that the luminous areas seen in the more remote Mars are fragments of a Morse Code which are being exhibited for our edification by intelligent organisms who have discovered our existence. For my own part I think you might just as well signal to an anthill or a beavers' lodge as to Mars !

I have ventured to put these views (for which I am responsible and not the Society) before you in no dogmatic

spirit, but merely as suggestions for you to follow out if any of you think them worth adoption as furnishing a working hypothesis. There is work to be done in the direction I have indicated, and it involves an immense range of study. You must go beyond the ephemeris, and spherical trigonometry and the calculus if you would fit yourselves to undertake the gigantic task. You have to search for analogies in departments of science which some may deem utterly alien, or foreign, to Astronomy. But the quest is, I think, worthy of pursuit. Here, however, let me note that analogy in these matters must not be our only guide. Hume, in one of his works, lays down that there are two other guides, *viz.*, experience and actual observation; and neither of these can be neglected. Mythological accounts of the creation of the Cosmos, and the origin of life may serve to hinder rather than help you in your investigations, which will be more hopefully advanced and directed if you study the chemistry of carbon and the colloids, and studiously follow the developments of the still young science of Radio-Activity. Remember in this connection that Radium emanations were detected in the spectrum of the Nova in Gemini. Astronomical physics teaches us that in the hottest suns, and in gaseous nebulæ, elements are to be observed of which Professor Moore of Liverpool says:—"It may well be that here we see to-day matter being created, and a varying balance established between energia and potentia, which may, through the long chain of events of increasing chemical complexity, followed later by organic complexity of living organisms, lead to an inhabited world." (Moore's Origin and Nature of Life, p. 39.) But however that may be, for the members of our Society the careful prosecution of observations, and the drawing of logical deductions from them, should be regarded as a duty imposed on us by the mere fact of membership. In conclusion, let me say that a Society like ours serves a distinctly useful purpose if only it enables people to keep their heads, and to investigate and weigh the evidence adduced for such claims as that the planets are inhabited replicas of our own world. The problems involved are essentially a question of evidence; and for myself I do not see any reason whatever to resile from the position I took up in the paper I read at your meeting of the 30th April 1912. Now, as then, I for my part, can only subscribe to what Mr. Arthur Hinks—no mean authority—says when closing his discussion of Professor Lowell's claims on behalf of Mars: "We can only say there is as yet no proof at all of the actual existence of intelligent life on any world but ours."

W. J. SIMMONS.

31st October 1913.

JEPPO, MANGALORE;
20th October 1913.

To

THE EDITOR,
Journal of the Astronomical Society of India.

DEAR SIR,

A Brilliant Meteor.

At about 7-40 P.M., S. T., on the evening of the 18th, I observed a very fine meteor which appeared to start from Ophiuchus about R. A. 16—Dec. 8° S. It showed no apparent disc, but was brighter than Sirius, with a thin but very bright tail of about 15 degrees in length. It travelled very slowly, as it took about fifteen seconds to reach the Fishes, where it faded away in about R. A. 1—5° N., thus covering about 135° of longitude. I conclude from its showing no disc, and from its slow progress, that it must have been very distant. It was a most beautiful spectacle.

Yours faithfully,
HENRY HART.

List of Donations for Conversazione.

	Rs.	A.	P.
Donation from Mr. W. J. Simmons ...	100	0	0
,, from Col. S. G. Burrard ...	50	0	0
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U. L. BANERJEE,
Treasurer.

Extracts from Publications.

Night.

Thy retinue, the constellations, Night,
With stately march across the heavens go!
And planets shine afar with steady light,
While countless hosts of starry systems show
Within thy Galaxy, the Milky Way.
The kindly Moon moves graciously along,
And turns, O Night, thy darkness into day—
For Queen is she of all the shining throng!
Such wondrous orbs as thou revealest, Night,
Can men yet doubt a Power controlling all?
Long ere these mighty suns have lost their light,
What scenes and changes shall our souls enthrall?
Unharmed, 'mid wreck of Time, shall they not stay,
Till thou, O Night, art merged in Endless Day?

ALICE BERLINGETT.

[*Popular Astronomy for August and September 1913.*]

The Parallax of Nova Geminorum (2).

Frederick Slocum.

Nova Geminorum (2) was discovered by Enabo at Dombass on March 12, 1912. The maximum negative parallactic displacement of the star occurred shortly after that date. A series of plates with the 40-inch refractor for the determination of its parallax was begun on March 18. Four plates were secured during that month, each having two exposures. Six months later, when the star was approximately six hours west of the Sun, six more plates were obtained at the time of the maximum positive displacement. And again six months later, in March 1913, five more plates were added at the second negative epoch.

When the first plates were exposed in March 1912, the star was of about magnitude 5. Six stars of nearly uniform brightness and symmetrically arranged around the Nova were selected for comparison stars. The mean magnitude of these stars is about 9·5.

In order to avoid errors due to difference in magnitude between the Nova and the comparison stars, the rotating disc was used with the sector opened about 10°, which reduced the light of the Nova by a little more than four magnitudes. As the Nova grew fainter the sector was opened wider and wider, until finally when the Nova was nearly down to the ninth magnitude, the rotating disc was removed altogether. Thus throughout the whole series the size of the image of the Nova on the plate was kept practically constant.

A least square reduction of the measures of the 30 exposures gives for the relative parallax of the Nova

$$\pi = + 0''{\cdot}006 \pm 0''{\cdot}007$$

and for the proper motion in right ascension

$$M_\alpha = -0^s{\cdot}0003 \pm 0^s{\cdot}001.$$

The proper motion in declination was derived from seven plates by a less rigorous method

$$M_\delta = + 0''{\cdot}036 \pm 0''{\cdot}016$$

The above value of π is relative to the weighted mean parallax of the comparison stars. From Kapteyn's table, the average value of the parallax of stars of the magnitude of these comparison stars is + 0″·005. Applying this we have for the absolute parallax of Nova Geminorum (2)

$$\pi = + 0''{\cdot}011$$

corresponding to 296 light years.

YERKES OBSERVATORY;
May 15, 1913.

[*Popular Astronomy, August and September 1913.*]

The late Prof. John Milne, F.R.S., D.Sc.

John Milne, as he was called, and as he liked to be called by his friends, died on July 31, 1913, at his home in Shide, Newport, Isle of Wight. A man of great kindness of heart, as well as of great scientific achievement, his loss is mourned not only by many who have enjoyed his personal friendship, but also by the scientific world which recognizes the great services he rendered to seismological study.

Born in 1850 at Liverpool, John Milne was educated at Rochdale, Liverpool, and Kings' College, London, and afterwards passed through the Royal School of Mines. It is not perhaps generally remembered how many brilliant scientists owe their training to that institution. Huxley and Tyndell, Judd and Boys, are but a few of those whose well-known names will be found on the register of the old college in Jermyn Street.

Milne was primarily a geologist and engineer, and it was in that capacity that he entered the service of the Japanese Government in 1875. His attention was immediately directed to the study of earthquakes, for, as he himself would have remarked, they have lots of earthquakes in Japan. So thoroughly did he take up the matter, with a view to the practical saving of life and property, that he was made Professor of Seismology in the Imperial University of Tokio. While the practical side of earthquake study was his first care in Japan, the purely scientific side was not neglected; but it only reached its full development when he returned to this country in 1895, and within a few weeks set up his observatory at Shide.

Our space is too limited to explain fully how by patient and systematic observation and study Milne developed this new branch of physical science known as modern Seismology. It must suffice to point out that he proved that a sensitive pendulum would record the occurrence of an earthquake at remote points, and that the record shows the existence of different types of waves, some of which travel through the Earth and others round its surface. Hence he showed how to find the distance from the observatory to the place where the earthquake occurred. He established over 60 seismological observatories scattered all over the world, and by systematic comparison of the results showed how the new study gives a knowledge of the physical properties of the interior of the Earth.

The foundations of seismometry were thus laid by Milne, and the investigations of modern Astronomy and Geodesy

came within his philosophy. Since 1900 the principles established by Milne have been greatly developed by Wiechert and Prince Galitzin. Milne was greatly interested in this, and I have the best of reasons for believing that, but for his failing health, he would have adopted the principle of electro-magnetic damping so successfully applied by Galitzin to experimental seismometry.

Dr. Milne married a Japanese lady, Miss Noritsuna, to whom the deepest sympathy will be offered in her bereavement. The esteem with which Milne is still regarded in Japan was shown by the presence of Baron Kujo, brother-in-law of the Emperor of Japan, at the funeral service at Newport on August 5.

Cambridge, August 14.

GEORGE W. WALKER.

[*The Observatory, September 1913.*]

Observations of Variations in Colour along the Limit of Venus.

By S. F. Maxwell.

Ordinarily, the limit of Venus, for 30 deg. or so back, is of a uniform yellowish-white colour and very bright. But this uniformity is by no means constant. At times areas of considerable extent appear to be whitened more than usual; also areas may become paler than is customary. I here give some observations to show this. In locating the areas under observation, I met with the difficulty always found in trying to localise objects on a ball—I had no starting place. The best I have been able to do is to give the positions in degrees from the mathematical limits of the cusps and from the edge of the planet, the limb.

On June 4, 1913, there was 70 deg. from the tip of the south cusp, an area of unusual whiteness. It extended northward 37 deg. and inward about 40 deg. It was a most striking feature, being almost on the "backbone" of the crescent. (It might have been there before this date, for no observation had been made since June 1). On the 6th it was 41 deg. long, and faded. On June 11 I saw it 50 deg. long and 35 deg. wide. It was still markedly white, though less so than on the two previous occasions. The boundaries, which had hitherto been definite, as boundaries go on Venus, on the 13th became so vague that it was impossible to do more than guess where they were. The dimensions were not changed markedly.

From this date on to the 18th when it disappeared, it kept growing fainter and more indistinct, until it was lost in the general brightness of the limb regions.

On July 26, 1913, after six days of bad weather, I noticed that a region 20 deg. long and 30 deg. wide, whose southern boundary was 44 deg. from the south cusp, was fainter than ordinarily. It was of a more marked yellow colour. On this date I recorded the limb in the N as "generally white." On July 27 the paler area had extended itself 60 deg. S and 10 deg. N, making itself 36 deg. long. Its width was at least 55 deg. The cap on the north cusp had grown plainly visible, and the northern regions appeared whitened for about 50 deg. southward. On the 29th the southern pale area began to become indefinite in boundary, though still of a noticeable yellow colour. At the same time, the northern whiteness, which had up to now been general, began to form itself into a well-defined white spot, 35 deg. long and about 60 deg. wide in the widest place, and had a triangular appearance. Its northern edge was 11 deg. from the top of the north cusp. On July 30 the faint area seemed to have lost all boundary whatever, so that it was impossible to say where the yellow actually met the white. The white area in the N also began to show an indefinite margin. It was a little faded too. Things continued without much change till August 5, when bad seeing set in. The northern white area was much shrunken on that date, being 25 deg. long by 40 deg. wide. It was then 5 deg. from the top of the cusp. A curious fact was that it showed three gradations of colour, like bits of differently shaded paper laid one above the other. The innermost one, with a well-defined margin, was white, the outermost was only a little whiter than the normal planet surface.

On August 16 the faint area in the S was still there, not much changed. The N looked entirely normal. On August 22, the time of the next observation, the faint area, too, seemed about disappeared, and the limb had its normal appearance.

These observations were made just at dawn, for the most part. I would draw the picture of the planet as carefully as I could, and then measure it. It must be borne in mind that it is not possible to delimit markings on Venus as on Mars or Jupiter. One is fortunate if he can get a boundary at all. Consequently my per cent. of error is high here, being often 10 per cent. or more; but it is the best I can do under these circumstances.

Objective 2⅞ in.; powers 20, 40, 68, 136. Objective an excellent achromatic.

[*Monthly Register of the American Society for Practical Astronomy—September.*]

Variables.

(358) "Alpha Bóôtis (Arcturus), spectrum K, when looked at through a 2½ in. refractor, is sometimes one of the prettiest stars; it scintillates, and there are flashes of orange, green, red-orange—even approaching red at times, and blue-green—even approaching blue occasionally. It was formerly thought to be a reddish yellow, with pale lilac companion. The atmosphere seems to cause it to look yellowish-red—sometimes almost orangey—when low down, but light yellow when high up. Can these various flashes mean hat it is an exceedingly close multiple star? Perhaps, if watched by large telescopes, which admit of great magnification, some signs of separation, other than from a binary, migh be seen. I have thought there have been times when itstight was greater than 0·05.

α . Awingæ (Capella), spectrum G, 0·18 mag. I have thought that there has been something peculiar at times about the light of this star for many years before I knew that it was a close binary. Its light seems to vary; once it was so bright that I thought some cataclysm had happened, although I knew it was such a large star; but as it became hidden by clouds, and I did not see it again for some nights afterwards, when it appeared as usual, I thought I might have noticed it when at a maximum period of variation. So I have wondered whether it can be both a short period and a long period variable, which needs the times of variation finding out.

β· Cygni seems to be growing fainter at times; or is it a variable? or does the passing state of our changeable atmosphere make these changes?"

J. W. SCHOLES.

[*English Mechanic and World of Science—October 24, 1913.*]

Memoranda for Observers.

Standard Time of India is adopted in these Memoranda.

For the month of December 1913.

Sidereal time at 8 p.m.

	H.	M.	S.
December 1st	24	40	16
,, *8th*	1	7	52
,, *15th*	1	35	28
,, *22nd*	2	3	3
,, *29th*	2	30	39

From this table the constellations visible during the evenings in December can be ascertained by a reference to a star chart, as the above hours of sidereal time represent the hours of Right Ascension on the meridian.

Phases of the Moon.

		H.	M.	
December 5th	First Quarter	8	28	P.M.
,, *13th*	Full Moon	8	30	P.M.
,, *20th*	Last Quarter	9	45	P.M.
,, *27th*	New Moon	8	28	P.M.

Meteors.

Date.	Radiant. R.A.	Dec.	Character.
December 4th	162°	+58°	Swift; streaks.
,, *6th*	80°	+23°	Slow; bright.
,, *8th*	145°	+ 7°	Swift; streaks.
,, *8th*	208°	+71°	Rather swift.
,, *10th—12th*	108°	+33°	Swift; short; brilliant.
,, *12th*	119°	+29°	Rather swift.
,, *20th—25th*	168°	+33°	Swift; streaks.
,, *21st—22nd*	117°	+47°	Swift.
,, *22nd*	194°	+67°	Swift; streaks.
,, *31st*	92°	+57°	Slow; bright.

Planets.

Mercury—Is a morning star, rising an hour before the Sun at the beginning and end of the month, and nearly an hour and a half before at the middle of the month. At greatest elongation on the 11th 21° 1′ W.

Venus—Is also a morning star and keeps close to Mercury throughout the month; the two planets being in conjunction on the morning of the 3rd when Venus will be about 1½ degrees to the south of Mercury. She is approaching superior conjunction which will occur on February 12th. She rises about an hour before the Sun on the 1st and three quarters before on the 31st.

Mars.—Position on the 15th R. A. 7·37 Dec. 24° 48′ North in Gemini. He will be in conjunction with the Moon on the night of the 15th when the Moon will pass between him and the Twins.

Jupiter.—Position on the 15th R. A. 19·32 Dec. 22° 4′ South, in Sagittarius. He sets about three hours after the Sun on the 1st and a little more than an hour after on the 31st as he approaches conjunction with the Sun which will occur on January 20th.

Saturn—Will be in opposition to the Sun on the 7th when he will be on the meridian at midnight, in Taurus R. A. 4·54 Dec. 20° 50′ North, almost in a straight line between Aldebaran and Nath.

Uranus.—Position on the 15th R. A. 20·30 Dec. 19° 34′ South, sets in Capricornus two hours after the Sun.

Neptune.—Position on the 15th R. A. 7·58 Dec. 20° 12′ North, in Cancer.

Notices of the Society.

Election of Members.

The attention of members is invited to Bye-Law No. 14, regulating the election of persons who desire to join the Society. It is hoped that those who are already members will induce others to join. Forms of application can be had from the Secretary.

Change of Addresses.

It is particularly requested that when members change their addresses, they will kindly notify the new address to the Secretary. The omission to do this is likely to cause the loss of the JOURNALS and other communications.

Telegraphic Address.

The address of the Society has been registered at the Telegraph Office, Calcutta. Telegrams should be addressed "Astronomy," Calcutta.

The Library.

A subscription list exists and several members in Calcutta have subscribed and enabled the Council to make a beginning with the Library. Other members outside Calcutta, however, have not, except in one or two cases, yet come forward, and as the Library will be one of the most important adjuncts of the Society, and will be available to members both in and out of Calcutta, those who have not yet done so are invited to help the Society in making progress with this important branch of the work. Suggestions as to useful books for the Library will also be welcomed by the Librarian.

A number of books have already been received and can be borrowed by members in accordance with the Bye-Laws.

The books available can be ascertained from the Assistant Librarian. The reading-room of the Society in the Imperial Secretariat is now opened for the use of members daily from 5 to 7 P.M., except on Wednesdays and holidays, and from 3 to 5 P.M. on Saturdays unless that day is a holiday.

The Journal.

The following charges have been fixed for back numbers of the JOURNAL :—

For members.—Per copy 12 annas ; per volume Rs. 5.

The Star Chart.—As. 12 a copy.

For non-members.—Rs. 1-8 per copy.

The Star Chart.—Rs. 2 a copy.

Subscriptions.

Subscriptions for the current session fell due on 1st October 1913. Those who have not paid in their subscriptions are requested to remit them to the Treasurer without delay.

Papers for Meetings.

It is requested that drawings which accompany papers for reproduction in the JOURNAL may be made with Indian ink on white paper. This will insure a clear reproduction.

List of Instruments.

With a view to enable the Council to obtain a knowledge of the instrumental equipment of the members, it is requested that those members who possess any instrument suitable for astronomical work will kindly send details to the Director of Instruments of its kind, size and power.

Addresses of Officers.

Owing to inconvenience which has arisen from addressing the officers of the Society at their private address, it has been decided to receive communications on the business of the Society in future as follows :—

	To
Money Orders or letters containing money or cheques.	RAI BAHADUR U. L. BANERJEE, Office of the Accountant-General, Bengal, 3, Koila Ghat Street, Calcutta.
All other communications ...	(*Name*) D. N. DUTT, ESQ. (*Designation*) Business Secretary of the Astronomical Society of India, Imperial Secretariat (Treasury) Buildings, Calcutta.

It is requested that communications may be addressed accordingly.

Officers and Council.

FOR THE SEASON 1913-14.

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MRS. TOMKINS.

The Journal of the Astronomical Society of India.

VOL. IV.] SESSION 1913-1914. [No. 2.

Report of the Meeting of the Society held on Wednesday, 26th November 1913.

THE Ordinary Monthly Meeting of the Society was held on Wednesday, the 26th November 1913, in the Imperial Secretariat (Treasury Buildings), at 5 P.M.

In the absence of the President, Mr. P. C. Bose was moved to take the Chair.

The minutes of the previous meeting were read and confirmed.

The following list of presents received by the Society since the last meeting was announced and the thanks of the Society were then accorded to the donors :—

1. Monthly Notices of the Royal Astronomical Society (Vol. LXXIII, No. 9)—Supplementary number.
2. Journal of the British Astronomical Association (Vol. XXIII, No. 10).
3. Monthly Weather Review for June 1913 published by the Government of India, Meteorological Department.
4. Rivista Di Astronomia E Scienze Affini—Ottobre 1913.
5. Annuaire De L'Observatoire Royal De Belgique.

Chairman.—I will ask the Secretary to read Mr. Henry Hart's paper on "The Shifting Ecliptic." (*Mr. Hart's paper*).

Chairman.—I would propose a vote of thanks to Mr. Hart for his paper.

Chairman.—I would now ask Revd. Ridsdale to read his paper on "The Perturbation of the Moon's Orbit."

Mr. Ridsdale.—I may mention that as my paper is a very lengthy one I intend to read only one-half of it at this meeting and will give you the other half at the next meeting. (*Mr. Ridsdale's paper*).

Chairman.—If any of the ladies and gentlemen here present have any remarks to offer or points to discuss, will they kindly do so ?

Mr. Raman.—I think we are all greatly indebted to Mr. Ridsdale who has given us a remarkable and interesting summary of the existing knowledge of the Moon's motion. Mr. Ridsdale has expressed himself in a very intelligible manner, and I do not think we can see such a clear exposition in the books. These give us either a formidable array of mathematics or a scrappy collection of facts without the dynamical explanations which can lend interest to them.

One point which struck me was that in giving a brief list of mathematicians who have advanced the Lunar theory, we should not omit the name of Professor Ernest Brown, who of late years has brought the processes of mathematical calculation practically to a state of perfection. I am sure we all look forward with interest to hear the second half of Mr. Ridsdale's paper.

Chairman.—We may return a vote of thanks to Mr. Ridsdale for his interesting paper and look forward to hear the other half of his paper at our next meeting.

Mr. Raman.—There is one thing I should like to say before the meeting is adjourned. During the recent holidays (7th to the 10th November) I took a trip to Bankura for the second time to meet the Revd. Mr. Mitchell and discuss the results of our work on Jupiter during the present apposition. During my visit I took the opportunity of making some observations with Mr. Mitchell's 5″ Cooke refractor and these bore out what I mentioned at our annual general meeting of this year regarding the excellent performance of the instrument. I had some very striking views of Jupiter on all

four evenings. Incidentally I may mention that Jupiter has shown very remarkable features during this year. The great red spot was in conjunction with the south tropical disturbance, and its drift and the accompanying phenomena are a revelation to the observer who has not previously worked on the planet. At the edge of the North Equatorial band and inside the Equatorial zone we have had a series of remarkable oval arch-like structures. Mr. Mitchell and myself propose to contribute two or three papers to the Society's meetings during the current session giving the results of our observations of the planet.

While at Bankura I also made some observations of Saturn late in the evening when the planet was fairly high up in the sky. Using the 5″ Cooke, not only was the crape ring an easy object, but for nearly one hour while the definition was perfect, I made out Encke's marking in the A ring and held it steadily for practically the whole period. Encke's division, as you know, is regarded as a difficult object which even a 10″ refractor often fails to discover. The conditions for observing it are, however, at present very favourable. The rings are widely open and the planet can be had at a sufficiently high altitude for the best definition. In fact, viewing Saturn with a refractor of a little less than 3″ aperture some time ago, I made out Cassini's division, and this when I had never before viewed the planet with any telescope of larger aperture.

Since my return to Calcutta from Bankura I have been doing some work on Saturn with the 7″ Merz refractor belonging to the Observatory of the Indian Association for the Cultivation of Science. My observation of Encke's division was easily confirmed. Besides this, I distinctly saw two markings in the B ring. These were, however, very faint and seemed to indicate some kind of a definite structure in the B ring. Further observations of the planet are being continued. I have only to add as a reminder to those of our members who possess telescopes of more than 3 or 4 inches aperture that Saturn is now a fascinating object worthy of study.

Mr. Simmons.—May I remark that I have a 3″ and I have failed to discover the division that Mr. Raman says he saw with a telescope of that aperture.

Mr. Raman.—The instrument is a $2\frac{7}{8}$ inch refractor manufactured by Ducretet of Paris. Though rather an old one, it is in a very good state of preservation and the object glass is practically perfect. Using this instrument I was able to see the Cassini's division quite easily.

Mr. Ridsdale.—I was going to say that there were 3″ telescopes in existence long before Cassini's division was

discovered. I think it all depends on a person knowing a thing is there; he can then find it easily.

Mr. Simmons.—I understood from the advertisement when I bought the 3″ telescope that I would be able to see the division, but I may say in spite of all my hopes I failed to see it.

Mr. Raman.—I can safely say that should any one care to have a look through my 2⅞ inch telescope, he would see the line of division between the A and the B rings clearly enough this year.

Chairman.—As far as my experience goes, I think it all depends upon the excellence of the night. You cannot see anything on a night when the sky is muddy and the definition poor, but the point of discussion is that Mr. Raman saw the line of division with a 2⅞ inch refractor and Mr. Simmons was unable to see it with a 3 inch; I think this was probably due to the state of the atmosphere.

The meeting was adjourned.

The Shifting Ecliptic.

By Mr. Henry Hart.

In these notes it is attempted to explain some effects of the changes which occur in the obliquity of the ecliptic. The angle of the obliquity is not a constant. It is at present diminishing by a calculable fraction in every second of time, being at the rate of ·468 seconds of arc in every year. In the present year, 1913, it is calculated to be 23° 27′ 2·17″ as shown in the Diagram A G, and at the above rate of diminution, the obliquity will entirely disappear in the course of 180,389 years, when the ecliptic will coincide with the celestial equator, and the celestial north pole will be the pole of the ecliptic (Diagram B H). Presuming the procession of the equinoxes continues at the present rate during this period, Polaris will again be the polar star when the ecliptic and the celestial equator are on the same plane, as one

revolution of the circle in the heavens described by the wandering pole occupies about 25,868 years, and seven revolutions of that circle will therefore occupy 181,076 years, which very nearly coincides with the time by which the angle of obliquity of the ecliptic will disappear.

The effects of this disappearance of the angle of obliquity will be an entire cessation of the changes of the seasons as now prevail all over the globe. We have become accustomed to regard the successive changes from spring to summer, from summer to autumn, from autumn to winter, and from winter to spring again, as certain to recur, year after year, as do the quarter days. Milton, in "Paradise Lost," thus refers to the obliquity of the ecliptic, giving us the changes in our seasons, as having been established at the creation to endure for all time :—

> "Some say He bid His angels turn askance
> The poles of earth twice ten degrees or more
> From the sun's axle; they with labour pushed
> Oblique the centric globe; some say the sun
> Was bid turn reins from th' equinoctial road
> Like the distant breadth to Taurus with the sev'n
> Atlantic Sisters, and the Spartan Twins
> Up to the Tropic Crab; thence down amain
> By Leo and the Virgin, and the Scales
> As deep as Capricorn, to bring in change
> Of seasons to each clime; else had the spring
> Perpetual smiled on earth with verdant flow'rs
> Equal in days and nights, except to those
> Beyond the polar circles: to them day
> Had unbenighted shown, while the low sun
> To recompense his distance in their sight
> Had rounded still th' horizon, and not known
> Or east or west, which had forbid the snow
> From cold Estotiland, and south as far
> Beneath Magellan."

For some thousands of years before and after the year 182302 A.D. the sun will practically be on the equator day after day, and year after year, and will never be higher in the heavens elsewhere than the latitude of the place deducted from the zenith. Thus, at Calcutta the sun at noon will always be about 67½ degrees, and at London about 38½ degrees above the southern horizon; and, as recorded by Milton, there will be no night at the poles, where for thousands of years perpetual winter will prevail. In the temperate zone of the northern hemisphere, autumn will last through long ages.

The tropics will have no change from the torrid heat of summer, while continuous spring time will prevail in the southern temperate zone.

As time advances after the year 182302 A.D. the ecliptic, continuing its never-ceasing movement in the heavens, will separate from the celestial equator ; and in a further period of 180,389 years, *i.e.*, by A.D. 362691, the present conditions will prevail again ; only what is now winter will then be summer, and summer will be winter ; spring will be autumn and autumn will be spring. (Diagram C I).

A further lapse of 165,765 years will bring the date to A.D. 528456 when the angle of obliquity will have increased to 45 degrees (Diagram D J) and the effects of this will be that all possible variations of climate will prevail in all countries all over the world. Every latitude, at different times of the year, will experience all the changes from arctic cold to equatorial heat. In June the sun will be vertical over the latitude of 45° S. Between July and August it will be directly over the south pole. September will see it back again over 45°S., and it will cross the equator between October and November. Continuing its course northward, it will pass over the north pole between January and February, crossing the equator again at the end of April, and back to 45° S. in June. Such conditions as these, as must have prevailed about 163852 B.C. (Diagram L F) will account for the discoveries of fossils of tropical fauna and flora in the arctic regions.

By the year 874609 A.D. the ecliptic will be increased to its maximum obliquity of 90 degrees from the plane of the celestial equator, in the position shown by E K in the diagram, and by this time the variations in the seasons all over the earth will be excessive. In its orbit round the sun the earth will pass between the sun and the celestial north pole in June, and between the sun and the celestial south pole in December. For five months, from April to August, our north pole will suffer perpetual darkness and arctic cold, while the adjoining latitudes will do so in a less degree. In June (Diagram E) the sun will be directly under our south pole, while in December it will be directly over our north pole (Diagram K). In March and September it will be on the equator, as it is now at the equinoxes.

The subsequent movements of the ecliptic will result in the different conditions already described, being repeated, but with reversals of the seasons. Thus, 1220762 A.D. (Diagram F L) will be similar to 528456 A.D. (Diagram D J). In the year 1386528 the changes in the seasons such as we now enjoy will prevail again (Diagram G A). The other

changes can be followed on the diagram, until we come to the year 2771143 by which time the ecliptic will have completed a perfect revolution, and will be back again in its present position.

These anticipations depend for their fulfilment on the present attractions of the sun and the moon upon the earth being precisely maintained; but whether they will be so or not it would be hazardous to express an opinion, as it seems impossible to foresee what the effects of increasing years will have upon our primary and satellite. We are rather accustomed to look upon present values as fixed values, and the figures above submitted are only intended to indicate the climatic changes which will result if existing conditions continue.

The Diagram.

N. and S. represent the directions of the celestial north and south poles. In the figures of the earth, A to L, which mark its positions in the month of June, *n s* represent the earth's axis, and *ee* the equator. The 45 degree parallels of latitude are also shown.

A—G	ecliptic	in	1913 and 2771143 A.D.
B—H	,,	,,	182302 A.D.
C—I	,,	,,	362691 A.D.
D—J	,,	,,	528456 A.D.
E—K	,,	,,	874609 A.D.
F—L	,,	,,	1220763 A.D.
G—A	,,	,,	1386528 A.D.
H—B	,,	,,	1556917 A.D.
I—C	,,	,,	1747306 A.D.
J—D	,,	,,	1913071 A.D.
K—E	,,	,,	2259224 A.D.
L—F	,,	,,	2605378 A.D.

and in 163852 B.C.

The Forces which go to determine the Motions of the Moon in Space.

By the Revd. A. C. Ridsdale, M.A.

The problem of the forces which go to determine the Moon's motions in space involves many very elaborate and difficult mathematical calculations. The unique genius of Newton, who was the first to open up this new path of enquiry and the greatest mathematicians since his time, such as Laplace, Lagrange, Euler, Clairant, Adams, Airy and Leverrier, have all been at work upon the "Lunar Theory," and yet the problem is not even to this day completely solved. I will try and make my paper as clear and as little technical as possible, but the subject-matter is a difficult one, and in the nature of things it cannot be made so easy and obvious as, for example, a treatise upon purely pictorial or observational astronomy. I may remind you that the study of the celestial motions, involving as it does the study of so many of the mightiest and most universal forces in God's creation, is by far the most important branch of our science. An earnest amateur astronomer will scarcely be able to satisfy all his curiosity regarding the celestial sphere by merely gazing through his telescope again and again at the well-worn craters of the Moon, or the mere dozen or so objects in the skies, that have any interest for the possessor of only a moderate sized instrument. He will want to know, not only what the celestial objects look like through a telescope, but how they really move, and how fast and at what relative distance, etc., and above all the reason why. To possess a clear understanding and thorough grasp of the main principles which determine the motions of the Moon is of the utmost value to the earnest student of Astronomy, inasmuch as the Moon's orbital motions are, so far as we know at present, typical of all the other celestial motions throughout this Universe. Moreover the study of the various motions of the Moon has incidentally yielded most valuable information, such as, for example, the form of the Earth, the vicissitudes of the tides, the distance of the Sun, and consequently the magnitude of the whole solar system. But above all the Moon's motions and still more her irregularities have taught us the universality of the law of gravitational attraction. The motions of the Moon are moreover of the very highest importance practically to the navigator and geographer, since measurements of lunar distances and occultations of stars afford the most accurate

determinations of longitude. I will begin by reminding you of two very important laws in regard to bodies moving in space. The first is, that in the case of a body moving undisturbed along a straight line, the radius vectors joined from any point arbitrarily chosen outside that line to points along it, will always describe equal triangular areas in equal periods of time. The second law which should be remembered, is that any force applied along the line of the radius vector so as to deflect that body from its original motion in a straight line (such, for example, as the Earth's attraction on the Moon, regarded as the sole occupants of space), will not interfere with its sweeping out these equal areas in equal periods, and retaining the same orbital plane. Hence in all cases in which a body is moving under the influence of a central force, and under no other, we can deduce the following laws of motion :—

Firstly.—The areal velocity, or square miles per second, swept through by the radius vector, will always be constant at all parts of the orbit, or in other words, the radius vector will describe areas proportional to the time.

Secondly.—The linear velocity, or miles per second, will vary inversely as the distance at which the body will happen to be at any given moment from the central attracting force (the angular velocity varying inversely as the square of that distance).

These all important laws in regard to celestial motions were discovered as plain facts by Kepler, from his examination of Tycho's observational records. But it was Newton who first proved them to be the mathematically necessary and universal laws of motion. Newton further proved that if a body be moving in an ellipse, having a centre of force at one of its foci, then the force of attraction at different points in the orbit will vary inversely as the square of the distance from that centre. And this was an epoch-making discovery of vast importance in the science of Astronomy, as being the basis of the universal principle of gravitation. Newton was able to prove that it is the attraction of the Earth, which determines the main motion of the Moon in her elliptical orbit, and that this attraction is comparable with the amount of attraction or gravity at the Earth's surface. For at the Earth's surface, that is at the distance of the Earth's circumference from its centre, a body falls a little more than 16 feet, or 193 inches in one second. And since the Moon is sixty times further away from the Earth's centre than is a body at the Earth's surface, therefore a body at the distance of the Moon should fall according to

this law only one-sixtieth squared as far per second as it would do at the Earth's surface. It ought then to fall 193 inches diminished in the ratio of 1 to 3,600 or $\frac{1}{19}$ inch per second. And $\frac{1}{19}$ inch is just about the amount which the Moon is actually deflected towards the Earth in each second. It was from the satisfactory proof of the Earth's attraction on the Moon that Newton was led on to his great discovery of the universality of the law of reciprocal attraction between all the bodies in space. Hence each body is a centre of attraction extending infinitely into space, and hence results the almost infinite complexity of the celestial motions. He further proved by very subtle and beautiful calculations, that any body moving under the influence of a central mass, must describe some kind of conic. A conic section is the curve traced out by a point which moves in such a manner that its distance from a given fixed point called the focus continually bears the same ratio to its distance from a given imaginary fixed line called the directrix. When this ratio is unity the curve will be a parabola, when more than unity an hyperbola, when less than unity an ellipse. As then the curve must be a conic, it must be either an ellipse (a circle is only one form of an ellipse) or a parabola or else a hyperbola. What the particular conic would actually be in any given case, would depend upon the original or primitive velocity and direction imparted to the circulating body. It may be as well to remind you of the principal practical characteristics of these three kinds of curves called conic sections which are traced out by celestial bodies. And these curves are called conic sections, because, when a right circular cone (not any cone) is intersected by a plane surface, the boundary of the section so formed will be one or other of these curves.

Thus firstly, the ellipse is a plane of section which cuts completely across a right cone, coming out at both slanting sides, but lower down on one side than on the other. A parabola is a plane which cuts a right cone parallel to its opposite slant-side (that is at an angle equal to the constant angle which the generating line forms with the axis) but does not come out at both sides, and is such that its two extremities or legs continually approach each other but never meet, whereas the legs of an hyperbola (which cuts a cone otherwise than parallel to one of its slant-sides) diverge practically to infinity.

Now as the Moon does not fly away from, but goes round and round the Earth, it is obvious from the definitions we have given of the parabola and the hyperbola that she can

not be moving in a parabolic nor an hyperbolic curve. She must then move in an ellipse. To be more precise, however, both the Earth and the Moon describe similar ellipses (the Moon's path being eighty times greater than that of the Earth, because its mass is eighty times less) around their common centre of gravity. However, in treating of the motion of the Moon around the Earth, it is convenient in all mathematical calculations to reduce the motion of the Earth to zero, and the mass of the Moon to zero, ascribing the whole mass of the two bodies to the Earth, and all the motion to the Moon. Thus we can place the centre of gravity of the two bodies, not as it really is at about $\frac{1}{80}$ of the Moon's distance, or about 3,000 miles from the Earth's centre, but immediately at the Earth's centre.

Now we will first examine what would be the motion of the Moon around the Earth regarded as its fixed centre of gravity, if there were no Sun or planets to disturb her in her orbit. She would move round and round the Earth, for ever describing exactly the same ellipse, exactly obeying the mathematical laws of motion of two bodies in space, which I have mentioned. The Moon's motion in this ellipse is brought about in the following manner.

When the Moon is at apogee or at the point which is farthest from the Earth, the Earth's attraction then overcomes her velocity, and brings her towards itself with such an accelerated motion that she at length overcomes the Earth's attraction and shoots past the Earth as it were, her velocity at perigee prevailing over the Earth's attraction. She then gradually decreases in velocity until she again arrives at apogee, where the Earth's attraction again prevails over her velocity. This process, if the Moon were undisturbed in her orbit, would repeat itself indefinitely. Thus the radii vectores would for ever sweep out equal areas in equal periods of time; her lineal velocity would be always proportional to her momentary distance from the Earth, her angular velocity being proportional to the square of that distance; or stating the case in less mathematical language, if we compare the Moon at perigee and apogee, then at perigee the radius vector would sweep out a precisely equal area at perigee as at apogee, but the Moon's velocity would be greater than at apogee exactly in proportion as its radius vector would be shorter, and her angular velocity would be greater as the square of this proportion. Thus, supposing for simplicity's sake, that the Moon were twice as near the Earth at perigee as at apogee, then her linear velocity would be twice as great and her angular velocity four times as great at perigee as at apogee. The true amount

of her ellipticity can be calculated from the variation of her apparent diameter, which ranges from 29½ minutes to 33½ minutes of arc, which points to her ellipticity being about $\frac{1}{18}$th—over three times as great as the ellipticity of the Earth's present orbit. In order to predict the Moon's position in her ellipse, or in other words to form lunar tables, we must be acquainted with what are called the "elements" of an elliptical orbit. We must know, that is to say, the greater axis of the orbit, the ratio of eccentricity, which is the ratio of half the lesser axis to half the greater axis, the longitude of her perigee, and that of the ascending node, the inclination or the angular projection of her orbit to the plane of the ecliptic, and lastly the longitude of her epoch, or the starting point as it were for our calculations. The first two "elements" determine the nature of the Moon's orbit, the three following its position in space, and the last is the relation of her present position to what it was at a given point of time. The average distance of the Moon, found from its parallax, being about 60 × radius of the Earth, or 239,000 miles, and her ellipticity being known to be $\frac{1}{18}$th, it can easily be calculated that her distance from the Earth must vary from about 221,000 miles at perigee to about 253,000 miles at apogee, a difference of 32,000 miles. The number of miles which the Moon has to travel in each lunation, being π × mean radius (regarding her orbit as circular) is therefore 6·2832 × 239,000 miles, or about 1½ million of miles, or on the average 55,000 miles a day, or 2,300 miles or rather more than her own diameter in one hour, or 1,133 yards in one second. From the Moon's mean velocity per second (or what her velocity would be if she moved in a circle instead of an ellipse) can easily be found what her true velocity really is at any given moment by applying what is called the "Equation of the centre," thereby reducing her imaginary circular motion to her true motion in an orbit of ·055, or about $\frac{1}{18}$th ellipticity. Incidentally I may remind you that the true form of the Moon's orbit with reference to the Sun, is not any series of ellipses nor looped spirals nor cycloids nor even trochoids, but it is nothing else than the orbit of the Earth, with very slight depressions and elevations of its concavity towards the Sun at each New and Full Moon. The Moon's orbit (contrary to what is often imagined) is always concave towards the Sun, even when at the point nearest to the Sun. She will then only be about $\frac{1}{8}$ × distance from the Earth towards the centre of the chord, which joins the two points where she crosses the Earth's path at Quadratures.

As to the Moon's rotatory motion, I need only remind you, that owing probably to the Earth's attraction on some slight

protuberance on the Moon's surface (analogous to a fixed tidal wave) she always presents to the Earth the same face, and therefore she rotates synodically once in rather less than $27\frac{1}{3}$ days. In other words, the Moon rotates absolutely $13\frac{1}{2}$ times in a year, and relatively to the Sun and Earth $12\frac{1}{2}$ times. The actual rotatory motion therefore of a point on her equator would be about 10 miles an hour or $\frac{1}{104}$ × the corresponding rotatory velocity at the equator of the Earth. As the Moon's orbital velocity is variable, and her rotatory velocity is invariable, we consequently see from the Earth's surface sometimes a little in front of her so to speak and sometimes a little behind. This "libration in longitude" amounts to about $7\frac{3}{4}°$ either way. Thus we can see about 15° more of her surface longitudinally than if her orbital velocity were invariable, besides another degree in longitude, by reason of other inequalities in her orbital motion, which we are about to mention, as due to the Sun's disturbing influence. And as her polar axis is inclined $1\frac{1}{2}°$ to the plane of her orbit, and that again is inclined about 5° to the plane of the ecliptic, we can therefore see 5° + $1\frac{1}{2}°$ or $6\frac{1}{2}°$ beyond either pole according as the Moon is at one side or the other of her path around the Earth. Thus her "libration in latitude" is about twice $6\frac{1}{2}°$ or 13°. The net result of the Moon's librations in longitude and latitude is that we are enabled to see at one time or another $\frac{8}{15}$ × her whole surface instead of only $\frac{1}{2}$ of it. So far we have been treating of the Moon's motion as a simple ellipse around the Earth. We must now consider the far more difficult and complicated problems connected with the "disturbances" or "inequalities" of this original elliptical motion produced by the Sun's action. These perturbations or inequalities are in the nature of a superposition of small motions upon the main or normal elliptical motion of the Moon regarded simply as revolving about the Earth as its fixed focus. By acting unequally upon Earth and Moon the Sun destroys the mathematical exactness of the Moon's elliptical motion. Thus owing to the Sun's disturbances the Moon does not in fact move in any known or symmetrical curve, but in a path which sometimes approaches to and sometimes recedes from the true elliptical form, and her radii vectores do not sweep out equal areas in equal times. And the amount of the disturbing forces upon the Moon's orbit can be judged from the extent of her deviation from true elliptical motion. Although many of these perturbations are very small in themselves in each lunation, yet in the lapse of ages some of them accumulate so as to become very considerable, and may so modify the Moon's motions after long periods of time, as to render the original elements of her orbit

quite inadequate. It is utterly beyond the scope of a short paper like this, to describe any but the largest and most important of these inequalities. Over fifty of them are taken into account in astronomical ephemerides in longitude, and over twenty in latitude. To account for all the Moon's inequalities which are almost infinite in number, is even beyond the present power of mathematics to accomplish. We will content ourselves with trying to get a clear idea of some of the most important (because the largest) of these inequalities in the motions of the Moon. Now when two bodies revolve round their common centre of gravity, and a third body is present to modify or disturb their motions by its attraction, if this third body is very far away (or very small), its action upon the two former is called a "disturbance" or "perturbation," and this third body is called the "disturbing force." Thus in the case of the Earth, Moon and Sun, the Sun is the far away disturbing force, the Earth is the fixed central body and the Moon is the disturbed body. Now it must be thoroughly grasped and understood at the outset, that the disturbing power of the third body depends, not upon its force of attraction absolutely but upon the difference (whether this difference be in amount or direction or both) of its attraction upon the two bodies that it disturbs. The mean difference or overplus of attraction by the Sun upon Earth and Moon, does not amount to more than $\frac{1}{640,000}$ × gravity at the Earth's surface. And this disturbing force is continually varying according to the temporary configuration of the three bodies. As the Sun is about 400 times more remote than the Moon, the Moon is therefore alternately $\frac{1}{400}$ part nearer and $\frac{1}{400}$ part farther from the Sun at New Moon and Full Moon respectively. And it is from these unequal distances and therefore unequal attracting forces that the Sun's disturbing influence is due. If the Sun's attraction on the Earth and on the Moon were always equal and in parallel directions, then this disturbing force would be *nil*. Thus although the Sun's absolute attraction is more than double that which the Earth exerts on the Moon (for his attraction on the Moon + Earth's attraction multiplied by his mass and divided by the square of his distance of $\frac{320,000}{389}$, or more than double that of the Earth), yet his disturbing force is only $\frac{1}{179}$ × the whole force which keeps the Moon in her orbit. Hence at New Moon the Sun does not deprive the Earth of her satellite, in spite of his attraction being twice as strong as the Earth's because the Sun's attraction on the Moon at Full Moon is only very slightly greater than it is on the Earth. Thus in order to prevent the Moon escaping, the Earth has not to exert

an equal pull with that of the Sun, but only a pull equal to the difference of the amount of the Sun's pull upon Earth and Moon at the moment, and this difference of the Sun's pulls is always much less than the whole attraction which the Earth is able to exert upon the Moon. Both Earth and Moon fall towards the Sun together, this falling motion, of course, being combined with any other intrinsic motions which Earth and Moon may possess at the time. When it is New Moon, she is $\frac{1}{389}$th nearer the Sun than is the Earth. The Sun's disturbing influence then makes the Moon fall towards himself slightly faster than the Earth, the Earth's attraction on the Moon is thus diminished for the time being, and the Moon's curvature towards the Earth is diminished, and increased towards the Sun. At half Moon or quadratures, when Earth and Moon are at equal distances from the Sun, the Sun is pulling the Earth and Moon towards himself with equal force indeed but on converging lines, and thereby reinforcing the Earth's attraction on the Moon, rendering the Moon's orbit at quadratures rather more curved towards the Earth, than it would have been if there were no Sun disturbing her true elliptical orbit. The Earth's attraction on the Moon is thus weakened at Syzygies and reinforced at Quadratures, much in the same way as the tides are drawn away from the centre of the Earth, when in a line with the Moon's attraction (disregarding the effects of friction), and pulled towards the Earth's centre when at right angles to the line of the Moon's attraction. The force is directed away from the Earth, or the Earth's attraction is diminished at Full Moon as well as New Moon, because the Sun then attracts the Earth a little more than he attracts the Moon, thereby tending to separate them. Whilst the Sun is the only body which is able sensibly to disturb the Moon's elliptical motion by his direct action the planets do so indirectly, by disturbing the Earth's orbit and therefore slightly modifying the ratios of the distance of Sun, Earth and Moon. But before we enquire into the effects of the planets' attraction upon the Moon's orbital motions, we will first give our attention to the disturbances caused by the Sun alone. [*To be continued.*]

Extracts from Publications.

Planet M. T.

The mean distance of Eros from the Sun is 1,458, that of Mars 1,524, the mean distance of the Earth from the Sun being unity. When the small planet M. T. was discovered,

in 1911, it was seen that an orbit with the same perihelion distance as Eros and a slightly greater eccentricity, would satisfy the observations; but the observations have been so scanty that no satisfactory orbit has been determined. In the number of the Pub. Ast. Soc. Pac., from which the above paragraph is quoted, there happens to be an article by Mr. Haynes, also of California, who after describing the difficulties experienced in making observations of the planet, and, therefore, in computing an ephemeris, writes:—

"A very unfavourable opposition of 1911 M. T., occurred some time early in the present year. The brightness was in the neighbourhood of the twentieth magnitude. Dr. Curtis, of the Lick Observatory, kindly offered to make a search for the planet with the Crossley reflector, and ephemerides based upon the most probable orbit were furnished him. During the course of his observation he discovered three minute planets in the immediate neighbourhood of the positions indicated by one of the ephemerides. Enough observations of all three were secured to render it certain that none were identical with 1911 M. T. This failure to find the planet does not justify the rejection of the orbit upon which the search was based, because the predicted magnitude is very uncertain, and the planet may have been in the region photographed, but too dim to be reached even by the Crossley. A more favourable opposition will occur in 1915, and it is hoped that the planet may be recovered at that time."

[*English Mechanic and World of Science.—Oct. 31, 1913.*]

British Astronomical Association.

The President (Colonel Markwick) delivered the twenty-third presidential address at the annual meeting of the British Astronomical Association on October 29th at Sion College, taking for his subject the work of the observing sections since the foundation of the Association. Of these sections, now fourteen in number, the output for publication has filled seventy-five memoirs, containing more than 3,000 pages; but more than one-third has been filled by two sections—the Sun and Variable Stars—while just over another third has been contributed by Jupiter, Mars, and Meteors.

In view of Professor Pickering's dictum as to the small amount of valuable research open to the amateur with small instruments, Colonel Markwick drew special attention to several points on which further research is badly wanted. We still do not know the nature of sunspots, nor what the surface of the Moon is, nor the rotation periods of Mercury and Venus; and for all these problems work can be done by the amateur, in addition to the field allowed him by Professor Pickering in photometry, specially of variable stars, and the attractive regions of comet-seeking and double star measures. The work of the Association is recognised as quite valuable by such an authority as Professor W. H. Pickering, at present working in Jamaica, who desires to collaborate with M. Antoniadi of Meudon Observatory, who is Director of the Mars Section of the British Astronomical Association. Work is required especially for the sections that have not yet produced much, such as that of Aurora and Zodiacal Light, and especially of Double Stars, many of Struve's wide pairs having been much neglected in consequence of the concentration of powerful telescopes on the closer pairs. The four eclipse expeditions of 1896, 1898, 1900 and 1905 give great hope of valuable work to be done or attempted at the forthcoming eclipse of 1914, August 20. In proposing a vote of thanks to the President, Mr. Knobel recalled, from personal experience, the abortive attempts at co-operation in observing the Sun, Moon and Jupiter in the years 1860 to 1880, before the foundation of the Association.

[*English Mechanic and World of Science.—Nov. 7, 1913.*]

The Annular Nebulæ in Lyra.

To "X" (586, p. 342). Mr. Burt Newkirk, of Minneapolis, in 1902, determined the parallax of the star at the centre of the Ring nebula in Lyra to be 0·10″, and found that it has a proper motion of 0·180″ per year in direction of position-able 303·7 degree. This was found from measures of the star with respect to a 12th-magnitude star outside the Ring made by Professor Burnham in 1891, by Professor Barnard in 1898, and by measures of photographs by Professor Leavenworth, supplemented by measures of this 12th-magnitude star with reference to stars around. A few years later Professor Barnard, to continue the investigation, repeated the measures of this

central star with reference to the star outside, and these measures of 1903-04 did not verify the proper motion found by Mr. Newkirk, and as his determination of parallax depended on this proper motion, it seemed that the derived parallax must be fallacious. This was the opinion expressed by Professor Barnard in a paper in the "Monthly Notices" for 1906 January; but Mr. Newkirk replied later that his parallax determination was independent of the proper motion determination, and that he saw no reason to alter the value. It appears that the central star is considered to be part of, or rather the nucleus of, the nebula. I believe this is the only object of the class whose parallax has been determined; but I do not know on what grounds it is to be considered the nearest of the nebulæ.

[*English Mechanic and World of Science.—Nov. 14, 1913.*]

A Theory of Solar Phenomena.

The Sun is a liquid molten body, up to the level of spot nuclei, of a temperature between 6,000° and 7,000° absolute (compare my paper "The Constitution of the Sun," Astrophysical Journal, January 1909).

The liquid masses are of uniform density to great depth, which permits of an extended system of convection-current which are a necessity in every rotating fluid body contracting in consequence of cooling. In low latitudes, between 10° and 30°, the masses rise from the interior to the surface. A small portion turns against the Equator, there going down again; but the bulk streams, at the surface, to higher latitudes and is drawn in between 60° and the poles, returning to low latitudes in the depth. Superposed on this prime system are smaller convection-currents.

The Sun has an atmosphere as high as the highest prominences. The principal constituent of this atmosphere is coronium hydrogen, helium, and other gases and vapours forming but a small percentage.

The photospheric clouds, floating at a certain height above the liquid surface, and formed by the condensation of vapour rising from the liquid masses, just as terrestrial clouds are formed by the condensation of vapours rising from our oceans.

As to the density in the corona it has been asserted that there must be practically a vacuum, because comets had traversed that region without encountering there any resistance. That is an error. Comets 1843 I and 1881 I were discovered only after their perihelion, so that we cannot say whether they were disturbed or not. 1882 II was observed a week before perihelion, but here too we are unable to assert that it passed undisturbed for it had afterwards 3 nuclei, instead of 1 before. Further, 1843 I and 1882 II were visible on the day of perihelion (and only on that day) with the naked eye close to the Sun, a brilliancy quite unparalleled, which can only be explained by the assumption that the comets encountered there a resistance and blazed up as meteors do when entering our atmosphere.

Prominences are eruptions of coronium-gas, but not of hydrogen, helium and calcium, as they appear to be at first sight. A mass of gas, escaping from the liquid Sun, and entering the free atmosphere, must expand there, and is consequently cooling. But at the same time it must encounter in the atmosphere a certain resistance, which can be overcome only by compressing this atmosphere all round the expanding mass. Now compression of a gas makes its temperature rise.

The cooling by expansion or the heating by compression may be calculated from the formula :—

$$T_2 = T_1 \frac{\left(P_2\right)^{\frac{K-1}{K}}}{\left(P_1\right)}$$ (K being 1 : 41 for gases like hydrogen).

It results, therefrom, that whenever the pressure diminished in the ratio 1 to 0·1 the absolute temperature falls in a ratio 1 to 0·51, or if the pressure increases the temperature goes up in the same ratio.

The coronium-gas, escaping from the liquid masses, expands and cools, and is surrounded by a zone of compression in the atmosphere ; this zone, therefore, is heated and thereby again becomes visible in the spectroscope in approximately the forms of the coronium-eruption, though the latter itself is not observed by us. We thus have an explanation why the spectra of the prominences and atmosphere are nearly identical. The cooling in the jets, which must originate under enormous pressure within the Sun, goes at great heights of the atmosphere very close to absolute zero.

Quiet prominences, which occur in all latitudes, are caused by the escape of gas over extended areas from small, but very numerous, bubbles. The eruptive prominences (jets, flames, or metallic prominences), only occurring in the spot-zones or near to them, are caused by the rapid emptying of very large bubbles, which, while still at a considerable depth below the surface, already have diameters of hundreds of kilometres.

One volume of water at 0° C. absorbs more than 1,000 volumes of ammonia-gas, thereby doubling its volume, and gives out the gas again at 100° C. Even under high pressure the volume of the free gas would exceed the volume of liquid water in which it had been absorbed. Moissan has shewn that molten iron in a similar way very strongly absorbs atmospheric gas, that on further heating this gas is again set free in a sort of effervescence, and that only after still further heating does the true boiling begin. Thus we may assume that the like process is possible at the still higher temperature of the liquid solar masses. Where these come up in low latitudes with the full temperature of the interior, absorption of the coronium will not take place. But the radiation causes a cooling, and now absorption takes place ; the masses become saturated with coronium-gas. The secondary similar convection-currents carry these masses now into the interior, where they become re-heated, and in consequence the absorbed gas is set free again.

With a density of only 1·1 in the outer layer, each metre exercises a pressure of 3 atm., 1,000 kilometres (only about $\frac{1}{7\,5\,0}$ths part of the radius) 3,000,000 atm., which great pressure in relatively small depths reduces the free gas to very minute bubbles, which remain nearly stationary in the surrounding liquid.

The setting free of absorbed gases is greatly facilitated by stirring or shaking the absorbing liquid. If the relatively feeble terrestrial earthquakes are often capable of causing an observable tremor of the entire globe, then we must conclude that, by the enormous eruptions which we often witness on the Sun, very extensive areas will suffer a shaking which causes the absorbed gas to be set free and (if not in too great depths) to rise to the surface, and there to cause quiet prominences. These masses thus become poor in absorbed gases, and, if they have wandered through the depth of the Sun, cannot cause prominence phenomena to a large extent on reaching the surface in low latitudes. Consequently there are few or no eruptions, the masses are not shaken and retain the absorbed gas, so that after due time large eruptions can

take place again. In this way we may explain the periodicity of solar activity by means of the system of convection-currents.

When the free gas rises to the surface before it is drawn into the depth of the circulation, it cannot accumulate sufficiently into bubbles so large as we need to explain the great eruptions in the spot-zones. This accumulation, however, is possible when the gas is retained and has to go through the depth, and therefore the great eruptions or explosions, which are the cause (not a consequence) of spot-formation, only take place where the circulation comes to the surface, *i.e.*, in the spot-zones.

The pressure, which gives jets a velocity of hundreds of kilometres a second, must be enormous; Zollner calculated it to be about 68 millions atm. for not excessive cases. In the great heights to which these eruptions are thrown up, the pressure will be but a fraction of an atmosphere. As these eruptions endure often only for a few minutes, the cooling of the expanding coronium goes very near to absolute zero; the gas partly liquefies and even solidifies; a fall of coronium-rain or snow pours down on the glowing ocean and causes there a sudden cooling of the liquid masses; a spot is formed as a consequence of an eruption from the hot interior, but nevertheless as a product of cooling.

The spot—slag-island, as in Zollner's theory—lies imbedded below the photosphere, and a circulation commences above it, which goes outward below and inward at high levels.

The spots, floating on the liquid masses, must follow the drifts therein. Pursuing Carrington's researches in this respect, Sporer found for the period 1861 to 1880 the following latitude drifts of sun-spots:

Between	0° and 5°	...	0·00 km. per hour		Mean for both hemispheres.
,,	5° ,, 10°	...	5·27	,, ,,	
,,	10° ,, 15°	...	0·75	,, ,,	
,,	15° ,, 20°	...	3·58	,, ,,	
,,	20° ,, 25°	...	11·86	,, ,,	
Upwards of	25°	...	17·13	,, ,,	

The mean length of a stream-line in the great convection-current may be estimated to be 2 million kilometres, and if a revolution lasts 11 years the mean velocity comes out about 2·0 kilometres an hour, much less than the above figures. Considering, however, that the velocity in the currents varies inversely as the widths of the cross-sections in its different parts, it is clear that the velocities must be less than the mean at the surface and greater in the depth.

The rotation-period of the Sun, increasing with the latitude, may be explained, firstly, by Faye's hypothesis; the masses are coming up from the depth, not in a perpendicular direction, but in an inclined one; and, secondly, in Zollner's view by a trade-wind-like circulation in the atmosphere. The temperature of the liquid globe being lower in high latitudes than it is near the Equator there must be such a circulation in the atmosphere increasing in intensity with the latitude. On the Sun there are no continents which interfere with the drifts originated by the trade winds, and they thus can develop far better than they do on the Earth.

Besides the actual drift of the spot-islands, there occurs also an apparent motion due to the trade-winds. As they are blowing strongest against the east shore with the full temperature of the normal surface, they must cause on this side a dissolution more rapid than that which takes place on the opposite side. The position of spots being deduced from their apparent centre only, the observer thus finds a greater displacement, after some time, than has actually occurred.

If a spot lasts for a longer time it is because it is renewed by subsequent eruptions. The accumulations of gas—the great bubbles—may be arranged at random, although on the average in a nearly straight line; they then will take place at the same locality as the first eruption. As, however, the spot has undergone a displacement in the meantime opposed to the rotation, it now suddenly jumps back to its former position—a fact which has been observed long ago.

20. That spot-formation of a new cycle always sets in at higher latitude is explained as follows:—Those masses, saturated with absorbed gas, which are drawn into the depth definitely already between 50° and 70° will rise again earlier, and in about 30° latitude, as compared with those which go to the interior only between 70° and 90°, and therefore reach the surface again later and in lower latitudes.

20. Absorption of the Sun's radiation can only take place at higher, and therefore cooler, levels. The higher levels therefore again must possess a greater content of energy than would correspond to the adiabatic curve. For this reason no cooling in low levels can be explained by descending currents; these would always arrive there hotter than their surrounding.

J. F. SHERM. SCHULZ.

Hamburg, October 1913.

[*The Observatory.—November 1913.*

Memoranda for Observers.

[Standard Time of India is adopted in these Memoranda.]

For the month of January 1914.

Sidereal time at 8 p.m.

		H.	M.	S.
January	*1st*	2	42	29
,,	*8th*	3	10	5
,,	*15th*	3	37	41
,,	*22nd*	4	5	17
,,	*29th*	4	32	53

From this table the constellations visible during the evenings in December can be ascertained by a reference to a star chart, as the above hours of sidereal time represent the hours of Right Ascension on the meridian.

Phases of the Moon.

			H.	M.	
January	*4th*	First Quarter	6	39	P.M.
,,	*12th*	Full Moon	10	39	A.M.
,,	*19th*	Last Quarter	6	0	A.M.
,,	*26th*	New Moon	12	4	P.M.

Meteors.

	Radiant. R. A.	Dec.	Character.
January 2nd—3rd ...	230°	+ 53°	Brilliant ; swift, long paths.
,, *3rd* ...	156	+ 41°	Swift.
,, *11th* ...	220°	+ 13°	Swift ; streaks.
,, *14th—17th* ...	295°	+ 53°	
,, *25th* ...	332°	+ 58°	

The Planets.

Mercury—Is a morning star until the 25th when he is in superior conjunction with the Sun, and then becomes an evening star, but too near to the Sun to be visible.

Venus—Is also a morning star, but is approaching superior conjunction with the Sun which will occur on the 12th February.

Mars—Is an evening star, in opposition to the Sun on the 5th, this phase having last occurred on November 25th, 1911. Another interesting incident will happen on the evening of the 11th when this planet will be occulted by the Moon. His position on the 15th will be R. A. 6·48. Dec. 27°-1′ N. in the constellation of Gemini.

Jupiter—Is an evening star until the 20th when he will be in conjunction with the Sun in Capricornus. His position on the 15th is R. A. 20·3. Dec. 20°-49′ S.

Saturn—Is also an evening star in Taurus. Position on the 15th R. A. 4·42. Dec. 20°-36′ N.

Uranus.—Position on the 15th R. A. 20·37. Dec. 19°-8′ S. in Capricornus.

Neptune.—Position on the 15th R. A. 7·54. Dec. 20°-21′ N. in Cancer.

A very interesting assemblage of the planets will occur within the constellation of Capricornus, in which the same sets with the new Moon on the 26th. The Sun, Moon, Mercury, Venus, Jupiter and Uranus will all be within 8¼ degrees of longitude, and less than two degrees of latitude, which is much less than the space occupied by the four stars forming the quadrilateral of Canis Major.

For the month of February 1914.

Sidereal time at 8 p.m.

		H.	M.	S.
February	*1st*	4	44	42
,,	*8th*	5	12	18
,,	*15th*	5	39	54
,,	*22nd*	6	7	30
,,	*28th*	6	30	59

From this table the constellations visible during the evenings in February can be ascertained by a reference to a Star Chart, as the above hours of sidereal time represent the hours of Right Ascension on the meridian.

Phases of the Moon.

			H.	M.	
February	*3rd*	First Quarter	4	3	P.M.
,,	*10th*	Full Moon	11	5	P.M.
,,	*17th*	Last Quarter	2	53	P.M.
,,	*25th*	New Moon	5	32	A.M.

Meteors.

	Radiant.		Character.
	R. A.	Dec.	
February 7th—23rd ...	75°	+ 41°	Slow; bright.
,, *15th—20th* ...	236°	+ 11°	Swift; streaks.
,, *19th—28th* ...	155°	+ 14°	Slow.
,, *19th—26th* ...	58°	+ 72°	

The Planets.

Mercury—Is an evening star throughout the month and will be visible about the middle of the month when he sets about an hour after the Sun. He will be at greatest elongation, 18 degrees East, on the 22nd.

Venus—Is in superior conjunction with the Sun on the 12th, and then becomes an evening star, but too near to the Sun to be visible at any time this month.

Mars—Will be found in the constellation of Gemini. Position on 15th R. A. 6·25. Dec. 26°-52′ N.

Jupiter—Rises in Capricornus about half an hour before the Sun at the beginning, and about two hours before the Sun at the end of the month. Position on 15th R. A. 20·33. Dec. 19°-14′ S.

Saturn—Remains in Taurus. Position on 15th R. A. 4·39. Dec. 20°-38′ N.

Uranus in Capricornus. Position on 15th R. A. 20·45. Dec. 18°-40′ S.

Neptune in Cancer. Position on 15th R. A. 7·52. Dec. 20°-31′ N.

Notices of the Society.

Election of Members.

The attention of members is invited to Bye-Law No. 14, regulating the election of persons who desire to join the Society. It is hoped that those who are already members will induce others to join. Forms of application can be had from the Secretary.

Change of Addresses.

It is particularly requested that when members change their addresses, they will kindly notify the new address to the Secretary. The omission to do this is likely to cause the loss of the JOURNALS and other communications.

Telegraphic Address.

The address of the Society has been registered at the Telegraph Office, Calcutta. Telegrams should be addressed "Astronomy," Calcutta.

The Library.

A subscription list exists and several members in Calcutta have subscribed and enabled the Council to make a beginning with the Library. Other members outside Calcutta, however, have not, except in one or two cases, yet come forward, and as the Library will be one of the most important adjuncts of the Society, and will be available to members both in and out of Calcutta, those who have not yet done so are invited to help the Society in making progress with this important branch of the work. Suggestions as to useful books for the Library will also be welcomed by the Librarian.

A number of books have already been received and can be borrowed by members in accordance with the Bye-Laws.

The books available can be ascertained from the Assistant Librarian. The reading-room of the Society in the Imperial Secretariat is now opened for the use of members daily from 5 to 7 P.M., except on Wednesdays and holidays, and from 3 to 5 P.M. on Saturdays unless that day is a holiday.

The Journal.

The following charges have been fixed for back numbers of the JOURNAL :—

For members.—Per copy 12 annas ; per volume Rs. 5.

The Star Chart.—As. 12 a copy.

For non-members.—Rs. 1-8 per copy.

The Star Chart.—Rs. 2 a copy.

Subscriptions.

Subscriptions for the current session fell due on 1st October 1913. Those who have not paid in their subscriptions are requested to remit them to the Treasurer without delay.

Papers for Meetings.

It is requested that drawings which accompany papers for reproduction in the JOURNAL may be made with Indian ink on white paper. This will insure a clear reproduction.

List of Instruments.

With a view to enable the Council to obtain a knowledge of the instrumental equipment of the members, it is requested that those members who possess any instrument suitable for astronomical work will kindly send details to the Director of Instruments of its kind, size and power.

Addresses of Officers.

Owing to inconvenience which has arisen from addressing the officers of the Society at their private address, it has been decided to receive communications on the business of the Society in future as follows :—

	To
Money Orders or letters containing money or cheques.	RAI BAHADUR U. L. BANERJEE, Office of the Accountant-General, Bengal, 3, Koila Ghat Street, Calcutta.
All other communications ...	(*Name*) D. N. DUTT, ESQ. (*Designation*) Business Secretary of the Astronomical Society of India, Imperial Secretariat (Treasury) Buildings, Calcutta.

It is requested that communications may be addressed accordingly.

Officers and Council.

FOR THE SEASON 1913-14.

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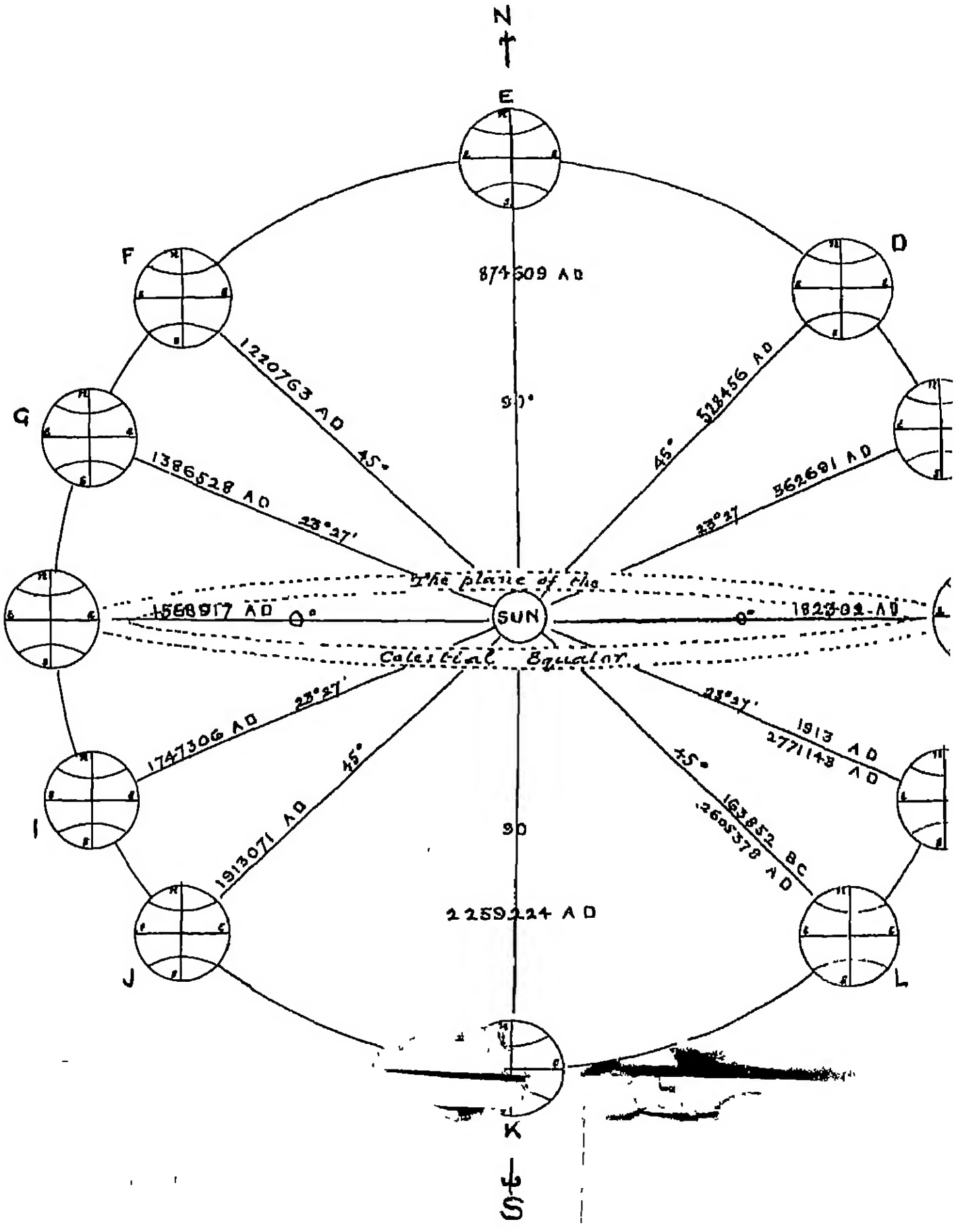


THE SHIFTING ECLIPTIC.

The Journal of the
Astronomical Society of India.

VOL. IV.] SESSION 1913-1914. [No. 3.

Report of the Meeting of the Society held on Tuesday, 23rd December 1913.

THE Ordinary Monthly Meeting of the Society was held on Tuesday, the 23rd December 1913, in the Imperial Secretariat (Treasury Buildings), at 5 P.M. Mr. W. J. Simmons, F.R.A.S., one of the Vice-Presidents, was in the chair.

The minutes of the previous meeting held on Wednesday, the 26th November 1913, were read and with one small alteration proposed by Mr. H. G. Tomkins, C.I.E., F.R.A.S., were confirmed.

The following presents received since the date of the last meeting were announced :—

1. Kodai Kanal Observatory—Bulletin No. XXXII.
2. Government of India, Meteorological Department, Monthly Weather Review for July 1913.
3. Sociedad Astronomica De Barcelona for November 1913.
4. South African Journal of Science for September 1913.
5. South African Journal of Science for October 1913.

The Secretary brought to notice that the last two publications had been received for the first time, and read a letter from the South African Association for the Advancement of Science, Cape Town, forwarding them and offering to exchange its journals with those of the Society. This proposal was agreed to and the thanks of the members were accorded to the Association and to the donors of the other publications.

The election by the Council at their meeting of the 18th December 1913 of Mr. Francis Cecil Gray, Calcutta, was confirmed.

A note by Dr. W. A. K. Christie of the Geological Survey of India on the Composition of the Tonk Meteorite was then read.

Mr. Tomkins.—I am much interested to find the elements sodium and potassium among those of which this meteorite consists. This may explain the effluence which appeared on the pieces of the meteorite and the fact that they showed a tendency to disintegrate during the time they were awaiting examination. I am also struck with the large number of elements present. I would suggest that we congratulate His Highness the Maharaj Rana of Jhalawar on the find now that we know its full value, and also accord him our thanks for the way in which he disposed of it. The meteorite now forms part of a very valuable and celebrated collection of meteorites in the possession of the Geological Survey of India and has proved a valuable contribution to science.

In closing the discussion Mr. Simmons said that the Society was deeply indebted to the Maharaj Rana of Jhalawar for having sent fragments of the Tonk meteorite to us. It had furnished the Society with material for discussion at several meetings, and to-night we had considered Dr. Christie's report on his analytical examination of the object. Mr. Tomkins had referred to saline constituents. What Mr. Simmons considered was of more interest was the existence of carbon amongst the elements detected in the analysis. Where there was carbon you had one of the most important elements involved in the constitution of living matter. On the other hand, nitrogen (an essential element where living matter was concerned) was not found amongst the constituents of the Tonk meteorite. So far no meteorite had indicated the existence of living matter coming from outside the Earth. The Chairman said the hearty thanks of the Society should be recorded to Dr. Christie for having taken the trouble to analyse the meteor and to furnish us with a report on the subject.

The next item in the agenda was a paper by Mr. Henry Hart on the Movements of the Planets in 1914. The Chair-

man called on the Secretary to read it. (*Paper by Mr. Henry Hart.*)

Mr. Tomkins.—Mr. Hart has used the terms "superior and inferior conjunction" and "opposition" freely in his paper, and to some of our members present these may be a little puzzling. For their benefit, if the Chairman will allow me, I will very briefly explain them.

Mr. Tomkins then explained the terms with the aid of the blackboard.

In closing the discussion on this item, Mr. Simmons said Mr. Hart's diagram would in due course be reproduced in the JOURNAL, and members would thus have an opportunity of studying it more carefully than was possible when it was handed round as it had been this evening. It would be of great service to those who wished to study the planets most familiar to ordinary observers. Mr. Simmons said he himself had never seen Mercury, but he comforted himself with the thought that the great astronomer Copernicus had never seen that planet. (*Mr. Tomkins.*—I have seen it three times. It is to be seen low down in the sky, etc.) Mr. Simmons said the diagram would help those who wished to study Venus, Mars, Jupiter and Saturn with which all ordinary observers were most familiar. He proposed that a hearty vote of thanks be recorded to Mr. Hart for the diagram.

The Chairman.—I will now call upon Captain Urquhart to read his paper on the Moon. (*Paper by Captain Urquhart.*)

Mr. Tomkins.—I do not think the mere question of distance of the Moon from the Earth is an insuperable objection to Captain Urquhart's theory that meteorites were shot out by the Earth to the Moon, because he refers to remote periods of time, and at one time it is highly probable that the Moon was much nearer the Earth than she is now, and in fact was probably a part of it. I was not aware that we had among our members a supporter of the meteoric impact theory. I confess I am myself opposed to it, and on several grounds. First of all, taking the slides we have just seen on the screen, it will have been noticed how much the seas for the most part resemble large flat-bottom craters. Captain Urquhart has suggested a different origin, but I find it difficult to regard the seas otherwise than large formations of a kind similar to some of the crater formations, such as Ptolemous. Except that one is smaller than the other they are similar in almost every respect. I should, therefore, put the seas at the top of the scale, and supporters of the meteoric theory, I think, usually admit this. Now some of these seas are found 400 to 500

miles across, and this seems to me to be against any meteoric impact origin on account of the enormous size of the meteorite required, and the fact that such impacts would probably cause far more serious effects on the Moon than the mere formation of the seas. Again, the central peaks in the craters are many of them very large—there is Copernicus, one about 7,000 feet in altitude. This means a mass of stuff which I am doubtful if the Earth could ever have thrown out. Most supporters of the meteoric theory go outside the Earth to the solar system for their meteorites which seems to me more likely than that the Earth shot them out, but personally I doubt both.

Again with the smaller crater pits, Captain Urquhart puts them down to small bodies which accompanied the larger one and fell round it. To this I think a serious objection exists in the fact that we find in several instances chains of three small craters in a line touching one another, and in some cases arranged with the largest at one end of the chain and the smallest at the other in descending magnitude. Such an arrangement seems impossible to the meteoric theory and to suggest rather lines of weakness and a volcanic origin.

I notice, however, that Captain Urquhart does not altogether deny volcanic forces on the Moon.

Generally speaking, however, it has always seemed to me that the meteoric theory requires such enormous forces, such terrific impacts and the presence of such a large number of foreign bodies of such gigantic size as to put the theory itself out of count. Our experience shows that nature, as a rule, works much more quietly and smoothly than this, and in the absence of some sort of indication that impacts of the kind have really occurred, I prefer to attribute the features of the Moon to some form of volcanic agency, as we do know that this agency exists in nature and we have some clear evidence of its effects.

Revd. Mr. Ridsdale.—Whilst thanking Captain Urquhart for his very interesting and instructive paper, I doubt whether the Earth's volcanic forces could ever have been sufficiently strong to have ejected such vast masses of matter, as must be supposed on the bombardment theory. I also think that the difference of character of the lunar crater from the terrestrial one could be quite satisfactorily accounted for by the vast difference of lunar from terrestrial gravitation. Speaking of the bolide theory, would it not be the case that missiles thrown out away from the line of centres of the Earth and Moon would fall on the latter at a considerable angle ?

Captain Urquhart.—No, most of those thrown out away from the line of centres would fall back on the Earth again, while the remaining velocity of those which came within the sphere of influence of the Moon would not be sufficient to affect materially the ultimate result at the surface of the Moon. As the hour is late, I must postpone my replies to the criticisms till a future meeting.

Mr. Raman.—I would ask what it is on Captain Urquhart's theory that produced the expulsion of the bolides from the Earth? If it was some kind of volcanic action, surely the very necessity for the theory disappears, since the Moon (being an offspring of the Earth as shown by Prof. Darwin) would partake of such volcanic nature and this would sufficiently explain the formations on it.

The hour being late, Mr. Simmons, in closing the discussion for the evening, briefly said there were two or three points on which he would like further information. He illustrated by diagrams on the blackboard the theory held by competent geologists with regard to the mode of formation of volcanoes. He also pointed out that while Captain Urquhart based his analogies on results obtained by firing bullets into vessels of molten lead, he himself preferred to look to the surface of the Earth itself for his analogies. In Nasenyth and Carpenter's work on the Moon there was a picture showing the configuration of the district around Naples. It closely resembled what we saw on the Moon's surface, and therefore suggested (he thought conclusively) that the structure of the Moon's surface could be better explained by reference to the known results of volcanic activity on the Earth than by the meteoric theory. Mr. Simmons added that the fragments of a bolide distributed themselves on the Earth in an ellipse, and by an illustration of the blackboard explained why this must be the case. The craters on the Moon, however, were circular, not ellipsoidal.

The meeting was then adjourned.

The Composition of the Tonk Meteorite.

By Dr. W. A. K. Christie.

The meteorite presented to the Astronomical Society of India by His Highness the Maharaj Rana of Jhalawar has been

* Published with the permission of the Director, Geological Survey of India.

transferred, with his permission, to the famous collection of the Geological Survey of India. It belongs to the rare group of ærolites known as carbonaceous chondrites ("K") in A. Brezina's classification. Its composition is given below :—

SiO_2	22·42
TiO_2	0·09
Al_2O_3	1·92
Cr_2O	0·12
FeO	22·28
Fe	0·33
Fe (as sulphide)	0·21
NiO	0·80
Ni	0·07
MnO	0·15
MgO	13·73
CaO	1·34
K_2O	0·36
Na_2O	3·24
P_2O_5	0·11
CO_2	0·13
SO_3	6·97
S (as sulphide)	0·12
S (free)	1·44
C	2·70
H_2O (below 106° C.)	10·74
H_2O (above 106° C.)	10·92
	100·19

Its total weight was 7·73 grams; 1·63 grams have been used for analytical and microscopic purposes.

Its noteworthy features are the high percentages of carbonaceous material and free sulphur it contains.

A detailed account will shortly be published in the *Records of the Geological Survey of India.*

The Movements of the Planets in 1914.

By Mr. Henry Hart.

The diagram shows the positions of the planets in respect to the Sun and the Earth on the day in each month on which the Sun enters the different signs of the zodiac. The positions on any intervening days can be easily spaced out. The heliocentric longitudes of the planets on the dates of the Sun's changes are :—

1914.	The Sun.	Mercury.	Venus.	Earth.	Mars.	Jupiter.	Saturn.	Uranus.	Neptune.
Jan. 21 .	300°	292°	238°	120°	111°	299°	76°	307°	116°
Feb. 19 .	330°	62°	334°	150°	125°	302°	77°	307°	117°
Mar. 21 .	360°	209°	22°	180°	138°	304°	78°	308°	117°
April 20 .	30°	295°	70°	210°	151°	307°	79°	308°	117°
May 21 .	60°	81°	120°	240°	165°	310°	80°	308°	117°
June 21 .	90°	221°	170°	270°	178°	312°	81°	309°	117°
July 23 .	120°	315°	222°	300°	193°	315°	83°	309°	117°
Aug. .	150°	118°	271°	330°	207°	318°	84°	309°	118°
Sept. 23 .	180°	239°	320°	360°	222°	321°	85°	310°	118°
Oct. 23 .	210°	330°	8°	30°	237°	323°	86°	310°	118°
Nov. 22 .	240°	135°	56°	60°	253°	326°	87°	310°	118°
Dec. 22 .	270°	244°	104°	90°	270°	329°	88°	311°	118°

[Minutes and seconds are omitted.]

The figures in the diagram, 1 to 12, below the orbits of the planets, represent their positions on the above dates: (1) representing January 21, (2) February 19, (3) March 21, and so on. It will be observed that the planets on the left hand of a line drawn through the Earth and the Sun on any date are evening stars, and those on the right hand are morning stars. The orbits of Mercury, Venus, the Earth and Mars are drawn approximately to scale. The others are not so. The letters A and P in the diagram denote the aphelion and perihelion positions of the planets in their orbits.

Mercury is a morning star until January 24 when he is in superior conjunction with the Sun, and becomes an evening star until March 10, when in inferior conjunction, being a morning star until May 16 in superior conjunction. An evening star from then until July 16 in inferior conjunction; then a morning star until in superior conjunction on August 30. An evening star then until November 7, when in inferior conjunction he will transit the Sun's disc. The transit commences at 9-57 A.M. and terminates at 2-9 P.M., Greenwich mean time. For the rest of the year he will be a morning star. He will be visible as an evening star during the end of February, the middle of June, and the middle of October; and as a morning star at the end of March, the beginning of August, and the middle of November.

Venus is a morning star until February 11 when she will be in superior conjunction with the Sun, and then becomes an evening star until November 27 in inferior conjunction, and a morning star for the remainder of the year. She will attain her greatest brilliancy on October 23.

Mars is a morning star until January 5 when he will be in opposition to the Sun, and will become an evening star until December 23 when he will be in conjunction with the Sun, and a morning star for the rest of the year.

Jupiter is an evening star until January 20 when he will be in conjunction with the Sun and become a morning star until in opposition on August 10, after when he will be an evening star for the rest of the year.

Saturn is an evening star until June 13 when he will be in conjunction with the Sun, and will then be a morning star until opposition occurs on December 21, and an evening star from then to the end of the year.

Uranus and *Neptune* are not visible without telescopic assistance. Their positions in the heavens can always be ascertained from the diagram.

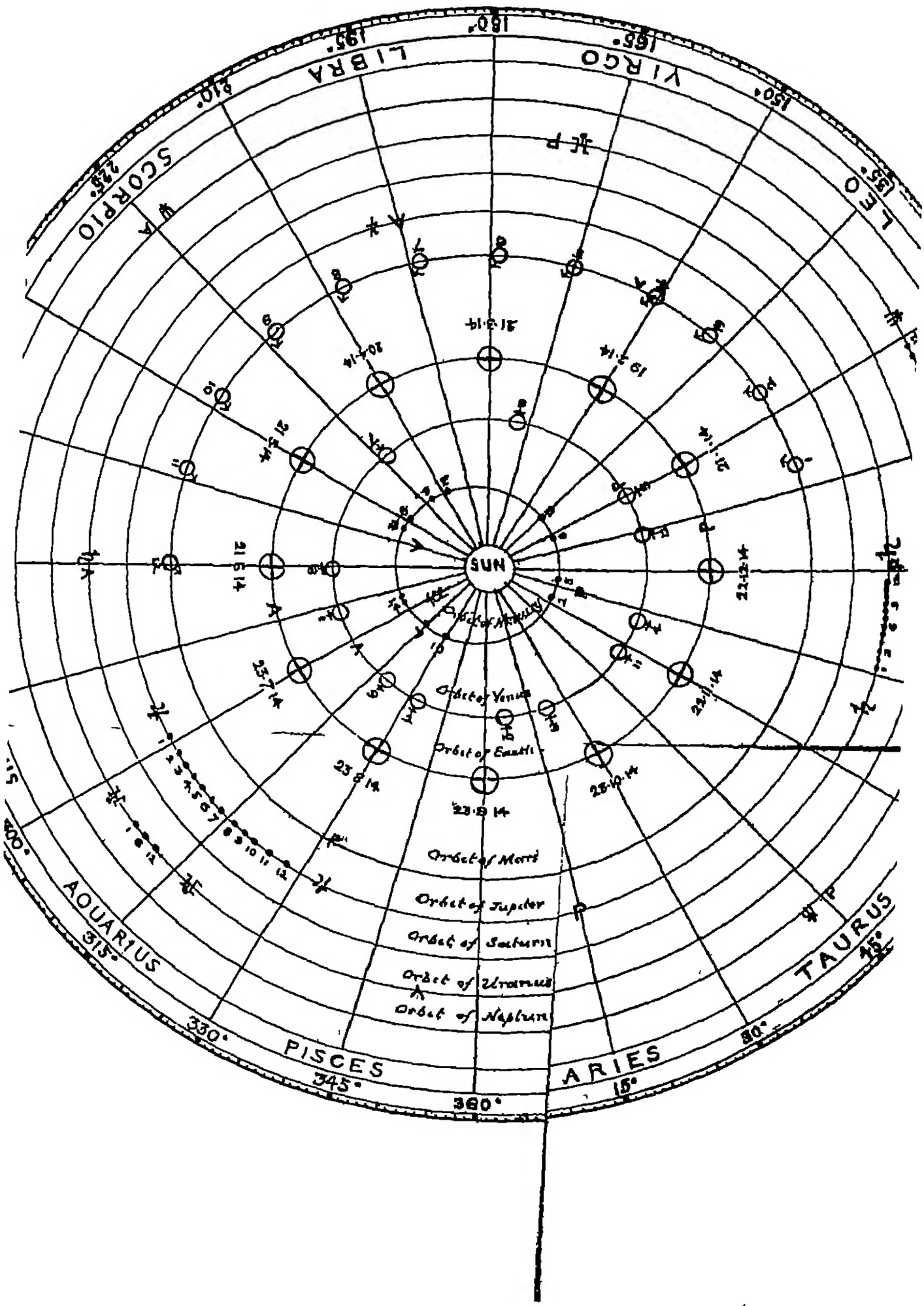
(The dates mentioned in the notes refer to astronomical time.)

Notes on the Moon.

By Captain A. M. Urquhart, R.A.

Some six months ago I carried out experiments by firing bullets into a bath of molten lead at various stages of solidification of the surface crust, and also into a block of solid

THE MOVEMENTS OF THE PLANETS IN 1914.



lead. The results seemed to me to throw considerable light on what is called the bolide or meteoric theory of the cause of the craters on the Moon. For the benefit of those who may not have been present when I read my first paper on the subject last May, I shall briefly indicate the main results obtained :—

(1) When the crust is thin the bullet breaks down a very large area roughly circular in form which sinks under the liquid interior. The rampart formed by the crust is further increased and heightened by the splashes all round.

(2) As the crust thickens the area broken up decreases and the ramparts become better defined and approach a more circular formation.

(3) When the bullet is fired into solid lead a typical crater is produced, the bullet mushrooming out evenly all round and leaving its base almost intact in the centre. The outer area slopes gently away from the rampart, while the inner wall is steep. If the bullet is of soft lead it leaves no central cone.

If we imagine the surface of the Moon to have been subjected to a bombardment during the gradual cooling and solidification of its crust, it seems to me we have a simple explanation of its otherwise unexplainable "craters." I have shown in my first paper that there seems to be no valid objection to presuming the Earth to be the source of this bombardment. The effect could not be caused by bodies from outside space, as such would seldom if ever fall vertically on to the Moon. But missiles from the Earth thrown out with sufficient force to bring them within the sphere of attraction of the Moon would always fall practically normal to the surface of the latter.

An objection was raised by one member that such bodies could not fall with sufficient velocity to cause such enormous depressions as we find on the Moon. Mr. Raman has very kindly calculated for me the velocity which a body, ejected from the Earth with sufficient velocity to bring it beyond the neutral point where the gravitational force of the Moon overcomes that of the Earth, would attain by the time it reached the surface of our satellite, and his figures have been corroborated by Mr. G. E. Sutcliffe.

If we suppose the distance between the two bodies to have been as at present, *i.e.*, about 240,000 miles, then the velocity attained by a missile from the Earth would be about 7,000 feet per second by the time it reached the Moon's surface—

a velocity surely sufficient to account for the deepest crater. But we need not assume that this distance has always been the same. In fact many astronomers, *e.g.*, Prof. Darwin, think it probable that our satellite was formerly much nearer than it is now; and if so, it may have revolved on its axis much faster. Thus it would present the whole of its surface to the Earth's bombardment, as it is not improbable that the unseen portion of the Moon's surface is also covered with craters.

But even if we bring the Moon within 1,000 miles of the Earth's surface, the velocity attained would still be over 2,000 feet per second.

The bolide theory is put forward as that which best accounts for the formations found on the Moon's surface. There are many objections to the theory that they may have been produced by volcanic action, among which the following may be stated :—

(1) The craters are utterly unlike the results produced by volcanic action as we know it. They are hollowed out like saucers while terrestrial volcanoes are mountain cones.

(2) The outer and inner slopes of the ramparts should be more or less similar if due to volcanic action, whereas we find the outer slope a gradual one of about 3°, while the inner sometimes approaches 60°.

(3) The terraces with their intervening valleys are explained neither by the volcanic theory nor by landslips.

(4) If the ramparts were due to the rain of volcanic matter, then we should expect a fairly even wall all round, but in most cases we find pointed peaks rising to as much as twice the height of the rampart. Volcanic action is very intermittent as we know it, and successive eruptions vary much in violence, yet if the circumvallations on the Moon were the result of volcanic action, it must have been wonderfully regular in each case during the time it lasted, to throw out matter in a regular rampart all round, and then suddenly to cease, and show no signs of intermediate stages between its utmost violence and its total collapse. Why should volcanic action cease suddenly at a rampart 60 miles or more in diameter, and then dwindle down to the comparatively feeble action which may have produced a central cone ? Why should there not be evidences of intervening stages in some out of the thousands of craters ?

(5) If the ramparts were produced as suggested we should expect a more perfect circular formation.

The impact theory, however, covers all these objections and we can follow the various formations in sequence according to their character and appearance as the surface gradually cooled, on the analogy of the bullet experiments.

First we have the large walled plains and smaller formations of a like nature with an irregular and sometimes not very clearly defined rampart, larger examples of which are Ptolemacus, Clavius, Grimaldi, etc. As the crust hardened the walls became sharper and better defined, *e.g.*, Plato.

Then we arrive at a stage when the crust could not be pierced or broken through, and we have a distinct change in the effect produced. We get formations which are usually classed under ring plains and craters proper. The more prominent features of these are :—

(*a*) A nearer approach to a circular formation.

(*b*) A gentle rise of the surrounding area towards the rampart with a steep declivity inside.

(*c*) Terraces and intervening valleys.

(*d*) Central cones in most cases.

(*e*) A floor greatly depressed below the outside surface.

These correspond exactly with the effect produced by firing a bullet into solid lead. The area surrounding the rim of the "crater" is raised gently, a deep saucer-shaped cavity is formed round which the bullet mushrooms out forming a terrace, while the base is left in the centre, forming the central cone. The formation of these terraces has not been explained by any other theory, and the fact that they are sometimes nearly as high as the original rampart does away with the idea that they are due to landslips.

The sudden impact of bodies travelling at such tremendous speeds as five or six thousand feet per second would cause solid matter to spread out like a fluid until it came to rest in the form of their terraces and central cones. The cases where there are no central cones correspond to that of the soft lead bullet which spreads out evenly over the cavity, leaving no trace of itself in the centre. In such cases we may presume the matter of the missile to have been less coherent. Another thing you will notice from the photographs is, that, as the surface of the Moon gradually hardened, the rims of the craters become sharper and better defined and more regular. In such a case as Clavius you will see the later formation superimposed on the earlier.

The question has been raised: "Why do not the maria or seas show as many traces of bombardment as the rest of the surface?" The most probable explanation is that the areas covered by the maria sinking at a comparatively late stage, were covered over by the liquid interior which obliterated most traces of the previous markings. This is plainly shown by the numerous rims of mountain rings and other formations which are scattered over the surface of the seas, and the ruins of formations round the edges, *e.g.*, Frascatorius. After the maria had cooled down, which would have taken place in a very short time owing to their shallowness, we get many traces of continued bombardment on them.

There are many interesting points which might be investigated in the light of this theory such as:—

(1) The numerous crater pits which are found in the neighbourhood of the larger formations, *vide* Copernicus. Is it probable that these may have been formed by a swarm of smaller missiles which accompanied the larger one?

(2) The nimbus or halo which surrounds all the craters which are presumably of later formation and the development of these into the great Ray systems. The fact that we find these rays in connection with craters of later formation only, suggests at once some connection between them and the hardening of the crust, and the familiar effect of the impact of a heavy body on smooth hard ice or the cracking of glass occurs to one's mind. Is the resultant whiteness due to some change in the albedo of the matter due to its brittleness and the vibration of the impact, or is it due to some salt which thus finds an easier outlet to the surface?

Does the greater whiteness of the rays from Tycho, for instance, indicate a later formation than Copernicus? Is Aristarchus later than Kepler and is the evidence of their brightness corroborated by the appearance of their ramparts?

(3) It is a well known fact that the maria are not all on the same level, *i.e.*, they do not all form part of the same sphere. Is the difference of level any indication of their age? If so, the deepest may be the more recent. The Mare Crisium is considered by Neisson to be the deepest of all.

These and similar questions require careful and painstaking observation and the best available instrumental equipment, but much may be learnt from the observations of others, and the excellent photographs of the Moon's surface which are now available.

"Selenology," says M. Fauth, "will have to include all the ring formations, even the largest, in one general explanation," and this the bombardment theory does.

The best test of any theory is whether it covers the observed facts, and from this point of view I think the bombardment theory is easily first.

It does not necessarily follow that all the formations were due to impact. It is only reasonable to suppose that volcanic action may have played its part, and we have evidence of this in the fact that some observers have seen volcanic cones with craters on their tops similar to what we find on the Earth. But these are so small as to be beyond the range of any but very powerful instruments. But the fact that we have evidence of volcanic action similar to what we find on the Earth is added evidence in favour of the bombardment theory, for it shows that the smaller gravitational force of the Moon does not (as has sometimes been maintained by upholders of the volcanic theory) cause volcanic action to produce results different from what we should expect.

I am much indebted to Mr. Tomkins for lending me the slides of the Moon which are now to be shown.

Extracts from Publications.

A Simple Method of Measuring the Heights of Solar Prominences.

By the Revd. A. L. Cortie, S.J., F.R.A.S.

A very convenient, simple, and quite accurate method of measuring the heights of solar prominences is by means of a photographed scale on glass, which can be fitted in the shoulder of the draw tube containing the positive eye-pieces of the viewing telescope of a spectroscope. If an accurate scale be drawn to any convenient size it can be reduced by photography, and, from the negative, glass positives can easily be obtained on very thin glass, like microscopic cover glasses. For instance, in the case of such a scale fitted to one of the eye-pieces of the Browning 12-prism automatic spectroscope at Stonyhurst, the diameter of the thin circular glass containing the scale is 20 mm. on which the scale of 100 divisions centrally placed covers 9·1 mm. The thickness of the glass is only 0·2 mm.

The following method can be adopted for finding the scale value in seconds of arc of each interval of the photographed scale. Let the image of the Sun be accurately focussed on the slit plate, and let the slit be adjusted in the N. and S. direction, which can be done by turning the spectroscope by means of the attached position circle into the required position. The attached position circle to the carrier of the spectroscope now reads 0°. Next turn the spectroscope through 90°, when the slit will lie parallel to the direction of the diurnal motion. Place the divided scale also parallel to the same direction, stop the clock, and let the Sun's image transit the slit, which is now radial to the E. and W. limits of the Sun's image. The spectrum, supposed sharply focussed, will now transit the divisions of the scale. Select some particular convenient division of the scale, and take the times when each edge of the spectrum band, corresponding to each limb of the Sun, transits it. This observation (and the mean of several can be taken) gives the interval in time required for the diameter of the Sun to cross the slit, or the spectrum band to cross any particular division of the scale. The accuracy of this observation can be conveniently tested by taking from the Nautical Almanac the sidereal time of the semi-diameter of the Sun passing the meridian, or if a mean time watch be used, the mean time of the same, the correction for each day to sidereal time being indicated in a foot-note in the Almanac, for the given day on which the observation is made.

At the same time as this observation is being made the interval of time taken by the sharp edge of the advancing spectrum, corresponding to the preceding or W. limb of the Sun, to cross any given convenient number of divisions of the scale—for example, 20—can be ascertained. One observer can watch the advancing edge of the spectrum in the viewing telescope and another can take the times. Let us suppose that the 10th division of the scale is selected. The observer at the spectroscope sees the advancing edge of the spectrum, and calls when it reaches the 10th division, and again when it reaches the 30th, and finally when the following edge of the spectrum reaches the 10th division. These observations can be repeated and controlled, and the mean of several taken as the final result. An example will illustrate the simple arithmetic then required to obtain the value in seconds of arc of the scale.

On October 12, 1912, as a mean of several observations, the time that the spectrum band took to cross the 10th division of the scale was 2 m. 10 s. and to cross the divisions 10 to 30, 5 seconds. From the Nautical Almanac the value of the Sun's

semi-diameter on October 1912 was 16′ 3·32″. This is for noon, but the change for a few hours before or after is immaterial in the present case, as it affects only the figures after the decimal point in the seconds.

Therefore 16′ 3·32″ of arc passed one selected scale division in 65 seconds of time.

Or $\frac{16' 3{\cdot}32''}{65}$ seconds of arc crossed in 1 second of time.

Or $\frac{16' 3{\cdot}32'' \times 5}{65} = \frac{16' 3{\cdot}32''}{13}$ seconds of arc crossed in 5 seconds of time 20 scale intervals.

Therefore 1′ 14·1″ arc = 20 scale intervals.

∴ value of 1 scale division or interval = 3·7″ of arc.

The mean height of the chromosphere on the same date was 2·2 divisions of the scale = 8·14″ corresponding to 3,460 miles.

[*Journal of the British Astronomical Association for Oct. 1913.*]

Jupiter's Equatorial Current.

Between the years 1887 to 1911 the motion of the equatorial current has been nearly uniform in velocity, apart from comparatively slight and temporary variations from time to time. The mean values of the rotation period during the 20 years, 1887—1906, from a very great number of observations by numerous observers, are 9 h. 50 m. 32·8 s. for the northern half of the current and 9 h. 50 m. 25·9 s. for the southern half.

But previously to the year 1887 it is well known that the rotation-period was considerably shorter than the above values as will be seen from the following figures, taken in part from the Monthly Notices, vol. 58, p. 14 :—

	H.	M.	S.		H.	M.	S.
1879 ... R =	9	49	59	1885 ... R =	9	50	14·3
1880 ... R =	9	50	7·6	1886 ... R =	9	50	22·9
1881 ... R =	9	50	10·2	1887 ... R =	9	50	22·4
1882 ... R =	9	50	9·7	1888 ... R =	9	50	27·8
1884 ... R =	9	50	12·4	1889 ... R =	9	50	30·3

These figures show clearly that there was an almost continual decrease in the velocity (or increase of rotation-period) from 1880 to 1889, and that in the year 1880 the rotation period had been as short as 9 h. 50 m. 7·6 s. It is, therefore, a fact

of the highest importance to find that a great acceleration in the velocity of the current has now set in nearly contemporaneous, moreover, with an acceleration in the motion of the red spot and of the material in some other Jovian latitudes.

It would be interesting to know if the southern half of the current participates in the acceleration of velocity of the northern half. Possibly Mr. Sargent or the Revd. T. E. R. Phillips could say if the S. equatorial spots also give a shorter period of rotation? In conclusion, may I be permitted to question the propriety of excluding spot No. 7 in deriving the mean? Probably this spot is a survival of the old order of things, but it is perhaps the best-observed spot of all, and there seems to be no sufficient reason for excluding it.

[*Mr. A. Stanley Williams in the Observatory for Dec. 1913.*]

In the case of the two Chinese astronomers, however, on whom the following flippant epitaph was composed, unnatural causes intervened to prevent their attainment of that ripe old age to which their profession almost entitled them. The two astronomers, named Hi and Ho, were appointed to watch an eclipse, but, having become intoxicated and failed in the fulfilment of their trust, they were condemned to be executed by the Chinese Emperor, Ho Kang. A short while after their death it was found that the eclipse was invisible!

Here rest the bones of Ho and Hi
Whose fate, though sad, was risible;
Being hung, because they could not spy
The eclipse, that was invisible.
Heigho! 'tis said a love of drink
Occasioned all their trouble;
But this is hardly true, I think,
As drunken men see double.

[*Mr. C. Edgar Thomas in the Observatory for Dec. 1913.*]

Mr. E. W. Maunder retired (in accordance with regulations) from the position of Superintendent of the Solar Department at the Royal Observatory, Greenwich, on November 6, 1913, after forty years' service. His work on solar and magnetic phenomena is too well known to need comment here. It may be recalled that he was for a time Editor (jointly or solely) of this Magazine from 1881 to 1887. He was Secretary of the Royal Astronomical Society from 1892 to 1896. In 1890

owing to his exertions the British Astronomical Association was established, and he is always justly regarded as its founder. In the office of President and otherwise he has since contributed largely to its present established position.

[*The Observatory for December 1913.*]

About the Earth-Moon System as expounded specially by the late Sir George Darwin, in effect, the day and the month are both becoming longer, which is in accordance with the doctrine of the conservation of moment of momentum. The Earth is slowing down and consequently is losing moment of M. and to compensate for this the Moon must gain moment. But it cannot do this by simply rotating faster and remaining at the same distance, for in that case Kepler's Third Law would not be satisfied. Now, the question is whether it is known from observation that this loss and gain are equal, and I do not think it is known whether the balance is exact. The effects on the motions of the Earth and of the Moon are so gradual that they can only doubtfully be detected by the most refined astronomical researches. The best, probably the only, way of settling such a point is by investigations of the circumstances—time and place—of ancient eclipses, such as those with which Dr. Cowell's name is connected. As just mentioned, the day and the month are both lengthening, but they are not lengthening at the same rate or, in other words, there are $27\frac{1}{3}$ days in the month now; but this has not been, nor will it always be, so. Sir George Darwin once pointed out "that the day must now be suffering a greater degree of prolongation than the month, so that we may look back to a time when there were more days in the month than there are at present. That number was once twenty-nine in place of the present twenty-seven; but the epoch of twenty-nine days in the month is a sort of crisis in the history of the Moon and Earth, for yet earlier the day was shortening less rapidly than the month: hence there was an earlier time when there was a reversion to the present smaller number of days in the month, and we have the curious conclusion that twenty-nine is a number of days in the month that can never be exceeded."

[*English Mechanic and World of Science—12th Dec. 1913.*]

Memoranda for Observers.

[Standard Time of India is adopted in these Memoranda.]

For the month of March 1914.

Sidereal time at 8 p.m.

		H.	M.	S.
March	*1st*	6	35	7
,,	*8th*	7	2	32
,,	*15th*	7	30	18
,,	*22nd*	7	57	54
,,	*29th*	8	25	29

From this table the constellations visible during the evenings in March can be ascertained by a reference to a star chart, as the above hours of sidereal time represent the hours of Right Ascension on the meridian.

Phases of the Moon.

			H.	M.	
March	*5th*	First Quarter ...	10	33	A.M.
,,	*12th*	Full Moon ...	9	48	A.M.
,,	*19th*	Last Quarter ...	1	9	A.M.
,,	*26th*	New Moon ...	11	39	P.M.

There will be an eclipse of the Moon on the 12th, but it will not be visible in India as the first contact with the penumbra occurs at 7-11 A.M. after the Moon has set.

Meteors.

		Radiant. R. A.		Dec.	Character.
March	*1st—4th*	167°	+	4°	Slow ; bright.
,,	*13th—24th*	161°	+	58°	Swift.
,,	*18th*	316°	+	76°	Slow ; bright.
,,	*28th*	263°	+	62°	Rather swift.

Planets.

Mercury—Is an evening star until the 10th when he will be in inferior conjunction with the Sun and will be a morning star from then until the middle of May, but too near to the Sun to be visible this month.

Venus—Is an evening star but sets too soon after the Sun to be visible until towards the end of the month, when she will set about three quarters of an hour after the Sun.

Mars—An evening star, is still in Gemini. Position on the 15th R. A. 6·47 Dec. 25° 52′ North.

Jupiter—A morning star, rises in Capricornus two hours before the Sun at the beginning of the month, and three and a half hours at the end of the month. Position on the 15th R. A. 20·58 Dec. 17° 41′ South.

Saturn—An evening star, sets in Taurus about six hours later than the Sun at the beginning of the month, and about four hours later at the close. Position on the 15th R. A 4·43 Dec. 20° 52′ North.

Uranus in Capricornus. Position on the 15th R. A. 20·50 Dec. 18° 18′ South.

Neptune in Gemini. Position on the 15th R. A. 7·49 Dec. 20° 37′ North.

Notices of the Society.

Election of Members.

The attention of members is invited to Bye-Law No. 14, regulating the election of persons who desire to join the Society. It is hoped that those who are already members will induce others to join. Forms of application can be had from the Secretary.

Change of Addresses.

It is particularly requested that when members change their addresses, they will kindly notify the new address to the Secretary. The omission to do this is likely to cause the loss of the JOURNALS and other communications.

Telegraphic Address.

The address of the Society has been registered at the Telegraph Office, Calcutta. Telegrams should be addressed "Astronomy," Calcutta.

The Library.

A subscription list exists and several members in Calcutta have subscribed and enabled the Council to make a beginning with the Library. Other members outside Calcutta, however, have not, except in one or two cases, yet come forward, and as the Library will be one of the most important adjuncts of the Society, and will be available to members both in and out of Calcutta, those who have not yet done so are invited to help the Society in making progress with this important branch of the work. Suggestions as to useful books for the Library will also be welcomed by the Librarian.

A number of books have already been received and can be borrowed by members in accordance with the Bye-Laws.

The books available can be ascertained from the Assistant Librarian. The reading-room of the Society in the Imperial Secretariat is now opened for the use of members daily from 5 to 7 P.M., except on Wednesdays and holidays, and from 3 to 5 P.M. on Saturdays unless that day is a holiday.

The Journal.

The following charges have been fixed for back numbers of the JOURNAL :—

For members.—Per copy 12 annas ; per volume Rs. 5.

The Star Chart.—As. 12 a copy.

For non-members.—Rs. 1-8 per copy.

The Star Chart.—Rs. 2 a copy.

Subscriptions.

Subscriptions for the current session fell due on 1st October 1913. Those who have not paid in their subscriptions are requested to remit them to the Treasurer without delay.

Papers for Meetings.

It is requested that drawings which accompany papers for reproduction in the JOURNAL may be made with Indian ink on white paper. This will insure a clear reproduction.

List of Instruments.

With a view to enable the Council to obtain a knowledge of the instrumental equipment of the members, it is requested that those members who possess any instrument suitable for astronomical work will kindly send details to the Director of Instruments of its kind, size and power.

Addresses of Officers.

Owing to inconvenience which has arisen from addressing the officers of the Society at their private address, it has been decided to receive communications on the business of the Society in future as follows :—

	To
Money Orders or letters containing money or cheques.	RAI BAHADUR U. L. BANERJEE, Office of the Accountant-General, Bengal, 3, Koila Ghat Street, Calcutta.
All other communications ...	(*Name*) D. N. DUTT, ESQ. (*Designation*) Business Secretary of the Astronomical Society of India, Imperial Secretariat (Treasury) Buildings, Calcutta.

It is requested that communications may be addressed accordingly.

Officers and Council.

FOR THE SEASON 1913-14.

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MRS. TOMKINS.

The Journal of the Astronomical Society of India.

VOL. IV.] SESSION 1913-1914. [NO. 4.

Report of the Meeting of the Society held on Tuesday, 27th January 1914.

THE Ordinary Monthly Meeting of the Society was held on Tuesday, the 27th January 1914, in the Imperial Secretariat (Treasury Buildings), at 5 P.M. The Hon. Mr. W. A. Lee, F.R.M.S., the President, was in the chair.

The minutes of the previous meeting held on Tuesday, the 23rd December 1913, were read and confirmed.

The following presents received since the date of the last meeting were announced, and the thanks of the members were accorded to their donors:—

1. Journal of the Astronomical Society of Wales for 1912.
2. Government of India, Meteorological Department, Monthly Weather Review for August 1913.
3. Sociedad Astronomica De Barcelona for December 1913.
4. Journal of the British Astronomical Association for November 1913.

5. Monthly Notices of the Royal Astronomical Society for November 1913.
6. Rivista Di Astronomia E Scienze Affini for November and December 1913.
7. Formulæ for Atmospheric Refraction—Professional Paper No. 14—published by the Government of India.
8. Catalogue of the Library of the British Astronomical Association compiled up to July 31, 1912.

The election by the Council at their meeting of the 20th January 1914 of the Rev. W. S. Sutherland, M.A., D.D., Kalimpong, and of Babu Ambica Churn Law, Calcutta, as members of the Society, was confirmed.

President.—I would now ask Revd. Mr. Ridsdale to read the second half of his paper on the Moon. (*Mr. Ridsdale's paper.*)

President.—Ladies and gentlemen, I am sure we are very much indebted to Mr. Ridsdale for his paper on the forces which cause inequalities in the movements of the Moon; the mere list of them is sufficient to give us some idea of the extreme complications involved. A well-known astronomer has said that the mathematical consideration of the inequalities of the motions of the Moon may be likened to an infinite wall against which the most eminent mathematician may measure his mathematical height.

Mr. Tomkins.—I would like to remark that this class of paper is one of which we have not had great many. The first occasion on which a paper of the kind was introduced was by Dr. Mullick at one of our meetings. There was some hesitation about giving a paper of this class in our society of amateurs, and it was stated by some at the time that it would be clear over-head nine-tenths of the members. The Council decided at the time to put the paper before the meeting on the ground that though some of our members are beginners, it is not good to always live on milk and a little strong meat now and then is a useful tonic. We have had some strong meat this evening and the paper is difficult to discuss because we cannot swallow it like a bolus. We shall see it in print and have time then to think it over and grasp its details. Such papers as these are valuable to the Society, and I for one hope we shall have several more of them.

Mr. Raman.—Mr. Ridsdale's paper may be strong meat, but I think he succeeded in offering it to us in a peptonized form.

President.—I agree with Mr. Tomkins that this is not a paper to be merely discussed here ; it is one which ought to be studied in print to be understood and appreciated. It is such a difficult subject. I beg to convey to Mr. Ridsdale the thanks of the Society for the highly interesting paper which he has given us.

President.—I now call upon Mr. Raman to read his paper. (*Mr. Raman's paper.*)

President.—I may remark that critical observations of the Zodiacal light are not easy to make, and observations of the Zodiacal light opposite to the Sun are extremely few ; it is very seldom that one finds the sky clear enough to observe it, and in Calcutta there is little or no chance of any one observing it at all. It is only in the comparatively clear sky of a dry place like Bankura that such observation can be made. As to the chance of finding the Earth's shadow on the patch of light, I hardly think the conical shadow of the Earth would be seen. Unless the extension of the Zodiacal light is limited to a distance of under 200,000 miles from the Earth, I think there would be no visible difference of illumination in the centre of the patch of light.

Mr. Raman.—Quite possibly the greater part of the cloud forms a long tail behind the Earth, or perhaps, the cloud is self-luminous. Either these causes or the excessive faintness of the whole phenomenon should explain our failure to see the hole due to the Earth's shadow.

Mr. Simmons.—I would like to say that Mr. Raman's observations are useful, and this is the time of the year (January) in which an observation of the Zodiacal light could be made even in Calcutta. It is also one of the Astronomical phenomena which can be watched without a telescope.

President.—Our thanks are due to Mr. Raman for his observations, but I may say that this is a subject that few have taken up.

As the hour is late, I am afraid that we will have to postpone Capt. Urquhart's discussion for the next meeting.

The meeting was then adjourned.

Forces that go to determine the Moon's Motion in Space.

By Revd. A. C. Ridsdale.

(*Continued from page 51*).

In all mathematical computations of the inequalities produced in the Moon's motion by the disturbing force of the Sun, it is convenient to resolve this disturbing force into its three rectangular components, known as the Radial, Transversal, and Orthogonal forces.

The Radial acts in the direction of the radius-vector (either towards or away from the focal centre). *The Transversal* acts along the line of the Moon's orbital path, so as to either accelerate or retard her motion. *The Orthogonal force* interferes with the plane of the Moon's orbit, generally tending to bring her into the same plane as the ecliptic. It chiefly results in the retrogressive motion of the Moon's nodes. The two opposite kinds of radial force are called the *Differential* and the *Constrictive*. In other words the radial force at one time tends to separate the Moon from the Earth, and at another time to pull them together. The radial force is differential or separative at Syzygies, or new and full Moon, when Earth and Moon are in a line with the Sun. The result is that the Earth's attraction is then lessened by about 1/89th.

At Quadratures or half Moons, when Earth and Moon are at right angles to the Sun, the radial force is constrictive, adding to or reinforcing the Earth's attraction by about 1/178th. The constrictive force is only about half as powerful as the differential. The radial forces vanish entirely at four points on the Moon's orbit, which are situated at about 36° on either side of the line of Quadratures. The Moon at these points is drawn neither away from nor towards the Earth.

The Transversal force is zero at both Syzygies and Quadratures, but at its maximum at the points 45° from Syzygies and Quadratures. Whilst the differential radial force always acts away from the line of Quadratures and the constrictive force always acts towards the line of Syzygies, the transversal force combines the two in affecting the Moon's velocity. Thus from new Moon to half Moon the transversal force is against or retarding the Moon's forward motion. During the second

quarter, it accelerates her, during the third quarter, or from full Moon to the waning half Moon, the transversal force is again retarding her, and for the last quarter, back again to new Moon, accelerating her.

The Orthogonal component which produces irregularities in the Moon's latitude, tends in general to draw the Moon towards the plane of the ecliptic. It neither influences the form of the Moon's orbit (this is done by the two kinds of radial force), nor her velocity (this is done by the transversal force), but it disturbs the plane of her orbit, chiefly by way of making the Moon's nodes revolve backwards. The nodes regress rather more than $1\frac{1}{2}°$ in a month, accomplishing the entire circle in about 19 years. So much for the rectangular components of the Sun's disturbing influence on the Moon's orbital motions. We will now enquire into what are the principal effects thereof. Now, in spite of the immense labour that has been expended by the ablest mathematicians upon the so-called "Lunar Theory," it is still, as we have said, incomplete and even slightly incorrect. Thus after a few years the lunar tables begin to get wrong, and have to be made out afresh, the Moon being frequently behind or before her predicted place by as much as 4″ of arc which is equivalent to about 4 miles along her orbital path. The number of "perturbations" or "inequalities" in the Moon's motions is indeed countless, but such small inequalities as do not disturb the Moon is her orbit by more than, say, 1/20th of a second of arc or 80 yards, can be safely ignored without any practical loss. It will be sufficient, for the purposes of my paper, to point out only the largest and most important effects of the Sun's disturbing action on the Moon's motions.

And first we will take *The Advance of the Moon's Apsides.* This movement of the line of the Moon's apsides, or advance of her perigee, is caused chiefly by the radial component of the Sun's disturbing force. The effect is brought about in the following manner. Whenever the Moon's perigee or apogee, or in other words the Moon's apsides or major axis, are at Syzygy, or in line with the Sun and Earth, the radial force being then differential, lessons the power of the Earth to pull her round so to speak. The Moon therefore goes on further in her course than she would otherwise have done before she turns the corner, hence the line of the Moon's apsides will advance in the direction of the Moon's motion. When, however, the line of apsides are in Quadrature, or at right angles to the direction of the Sun, the opposite effect takes place. The Sun's disturbing force is then constrictive, and hence

the Moon turns the corner so to speak earlier, and consequently the line of apsides regresses. But as the differential force is double that of the constrictive force, therefore the differential force prevails, and therefore the Moon's apsides progress twice as much as they regress. And not only so, but it must also be taken into consideration, that the Sun goes round the same way as the apses whenever they advance, staying in Company with them, whereas when they recede the Sun only meets them—thus indirectly augmenting their tendency to advance. The result of all this is that the line of apsides advances 6 the Moon's diameter, or about $3\frac{1}{2}°$ per month, or nearly 41° per annum, or accomplishes a complete, direct revolution in about $3{,}232\frac{1}{2}$ days, or in a period of rather less than 9 years. The motion of the Moon's perigee appears to be getting slower and slower as time goes on, being now 8″ in a lunation slower than in the time of Hipparchus. We will next consider the *Retrogression of the Moon's nodes;* as we have shown above, the orthogonal component tends in general to identify the plane of the Moon's orbit with that of the ecliptic. The orthogonal force is analogous to the precessional force, in that it affects the Moon's orbit much in the same manner as the precessional force affects the Earth's equatorial plane, causing thereby the retrogression of the first point of Aries. The orthogonal force causes the Moon's nodes on the whole to recede. Because when the Moon's nodes are before quadrature and after Syzygy, the node will in that particular lunation advance. Yet in all the rest of the orbit, the orthogonal force being towards the ecliptic, the nodes will recede. For as the Moon rises from the ecliptic the orthogonal force will cause her to rise at a less angle and descend at a greater angle, and therefore she will come down to her next node on the ecliptic a little sooner than she otherwise would have done, and thus the node recedes. And *vice versa*, as the Moon descends below the ecliptic, she will, owing to the effect of the orthogonal force, descend at a less angle, and will again ascend at a greater angle than otherwise. Hence she will rise to her next node earlier, and hence again her node will recede. Whilst then her nodes can sometimes advance, yet their retrogression greatly preponderates on the whole. They recede on an average about $1\frac{1}{2}°$ in the lunation, $19\frac{1}{3}°$ per annum, or revolve through the whole 360° in 6793·39 days or a little more than $18\frac{1}{2}$ years' period. When the Sun is in a line with the Moon's nodes, that is, when the nodes are in Syzygy (since then the Moon's orbit is in the same plane with the ecliptic) and also twice each month, when the Moon is at Quadratures, the orthogonal force vanishes altogether. And consequently at those times

there is no force to disturb the plane of her orbit, so as to make her nodes either advance or recede. I should add that the inclination of her orbit as well as the position of her nodes is affected by the orthogonal force. But the effect in this direction is very slight and nearly compensated for in each lunation, and entirely so in a whole revolution of her nodes. The secular inequality in the notion of the Moon's nodes depends upon the variation of the eccentricity of the Earth's orbit; as her velocity is accelerated the motion of her nodes is retarded and *vice versa*.

We will next notice the effect of the radial force upon the *lengthening of the Moon's sidereal period*, as we have pointed out above, the force of the negative or differential component is double that of the positive or constrictive force. And besides that, the differential force preponderates for 216° out of the 360° of the Moon's monthly orbit. The result is that for every lunation as a whole, the radial force diminishes the Earth's attraction on the Moon by about 1/359th part. It thus enlarges her ellipse, and consequently makes her month nearly an hour longer than it would have been.

Another very important inequality in the Moon's motion is the *change of the Moon's Eccentricity*. This was discovered nearly two centuries before Christ by Hipparchus, being the most considerable of all the Moon's inequalities. Hipparchus was able to discover it, because it very materially affects the times of eclipses, and it was the eclipses that the ancients chiefly studied and understood. The change of eccentricity is caused by the difference in position of the Sun in reference to the Moon's line of apsides. The eccentricity of her orbit varies according as to whether the Sun is towards the line of her major or minor axis, and the variation of her ellipticity due to this cause can be as much as 1/70th. The mean interval between successive conjunctions of Sun and perigee is about 412 days. This change of eccentricity, which is sometimes called Evection, causes the Moon to be displaced in her orbit by more than $1\frac{1}{8}$° backwards or forwards, or more than twice her diameter or about 4,500 miles as measured along her orbital path. Its period is the time the Sun takes in going round from perigee to perigee or about $1\frac{1}{4}$ years. *The Moon's variation* is another very considerable inequality. It is the transversal component of the Sun's disturbing force, which is mainly responsible for this perturbation. The transversal force tends, as we have said, to retard the Moon's motion from new Moon to first quadrature, and from full Moon to second quadrature, and *vice versa* in the other two quarters. Hence the result of this

inequality is, that the Moon is behind her undisturbed place at first and third quarters, and ahead at second and fourth quarters. She is most ahead and behind at the octants, her maximum amount being nearly 36′ of arc, or about an hour and twenty minutes measured in time, or about 2,400 miles measured along her path, or rather more than her diameter as seen from the Earth. This inequality called variation does not affect the times of eclipses, because it is zero at the Syzygies, and hence it was not known to the ancients. To Tycho Brane falls the honour of having first noticed this inequality.

We will next consider the *Moon's Parallactic Inequality*. This is an important disturbance, since it alone of all the disturbances yields a data for computing that all important quantity, the Sun's parallax. It was by observing that this inequality was greater than what it should have been on the old computation of the Sun's distance, that Hansen was enabled to correct the Sun's distance, reducing it by three million miles. The parallactic inequality is due to the fact that the ratio between the distances of Earth and Moon and Sun varies according to whether the Moon is at new Moon or full. The Moon being about 1/400th of the distance of the Sun away from us, this fraction is therefore the ratio of the parallax of the Sun to that of the Moon. The difference of the perturbing force at these positions is in the ratio very nearly of 200 and 203. The last great inequality that is perceptible even without telescopic aid is the *Moon's Annual Equation*. This may be regarded rather as an indirect perturbation by the Sun. It depends upon the fact that when Earth and Moon are nearer than the mean distance from the Sun, the Sun's disturbing influence will then be greater upon the Moon's motion, than when they are farther off and, since the Sun's differential or separative force prevails in each lunation, therefore during the summer-half of the year (when Earth and Moon are farther away from the Sun) the Moon will be less disturbed and therefore will approach the Earth, her orbit then contracting and therefore the month will be shorter, and *vice versa* in the winter-half of the year, the lunar orbit will be dilated, and the month will be longer. The maximum amount of this hurrying up and slowing down of the Moon's motion due to the annual equation is rather more than 11′ of arc or about 700 miles backwards and forwards in the Moon's orbital path. The annual equation is a periodic inequality, wholly compensating itself in the period of one anomalistic year, or the time from perihelion to perihelion again. The Moon is most before or behind her mean place in April and October, that is to say, after half a

year's excess of acceleration and retardation respectively. It may perhaps be as well to point out that the Moon's "mean" place always means her mean elliptical place. And her mean elliptical place means the mean place she would have if she moved in a circle when corrected by the "equation of the centre." We must not forget to make mention of a certain inequality in the Moon's orbital motions, which is sometimes overlooked. I mean the *inequality (chiefly in latitude) due to the elliptical shape of the Earth.* The Earth is an oblate spheroid or an ellipsoid of revolution. The mutual attraction between all the particles of the Moon's mass and all the particles composing the prominent mass at the Earth's equator (the Earth's ellipticity is about 1/305th) causes a considerable disturbance in the motions both of the Earth and the Moon. This inequality in the Moon's latitudinal position is the reaction of the Earth's axial nutation. Since the plane of the Moon's orbit does not coincide with that of the Earth's equator (where the excess of matter exists) it tends as we know to be drawn by the Moon's attraction into her orbital plane, the consequence of which is the nutation of the Earth's rotational axis. Hence *per contra* the Moon tends to be drawn into the plane of the Earth's equator. It must be remembered that the attraction of oblate spheroids differs from that of spheres in that spheroids do not attract, as though their whole masses were gathered at their centre, but they attract a distant body in the plane of their equator more than if that body were in the plane of their poles. The constant effect on the Moon's latitude due to this inequality is about 8″ of arc or about $7\frac{3}{4}$ miles above or below the path she would otherwise have pursued. The motion of the Moon's nodes and perigee are also affected by the Earth's elliptical shape but only to very small extent. I may add that the elliptical shape of the Moon herself has no sensible effect upon her motions. So far then I have spoken firstly of the Earth and Moon as two bodies alone in space; secondly, of the Earth and Moon as disturbed by a third body the Sun in various ways; and thirdly, as disturbed by the Earth's ellipticity; and now before I close my paper, I must just mention one other very interesting inequality, produced not by the Sun or the Earth, but by the planets. It is called the *Secular Acceleration* of the Moon's mean motion. This action of the planets is somewhat similar to that of the Sun which causes the Annual Equation. The planets are at present indirectly accelerating the Moon's motion by directly affecting the Earth's orbit. It must be remembered that the planets' direct action on the Moon must be practically nil owing to their exceedingly small mass and the great

distance of most of them compared with that of the Sun. Two centuries ago the then Astronomer Royal discovered that the month must be getting shorter. He was led to this conclusion by comparing the periods of ancient and modern eclipses. By calculating back to ancient times what the dates of eclipses ought to have been according to the modern lunar tables, he discovered considerable discrepancies between the theoretical dates and the dates as given by Ptolemy, proving that the month was gradually shortening. Laplace later showed that this shortening of the month was proportional to the square of the time, a fact which was proved by all the known ancient and intermediate eclipses. The Moon was then about 1° ahead of the position she would have occupied, but for this so-called secular acceleration. He further discovered that this increasing velocity was due to the Earth's decreasing eccentricity. Owing to the action of the planets, the Earth's orbit is still getting more circular or less elliptical, or its minor axis is increasing (the major axis and mean motions remaining the same) at the rate of 3,900 miles in a century, and it will continue to do so for about 24,000 years to come, when it will again gradually become more elliptical. If the Earth's orbit were to become a circle it would take 36,300 years to do so. But its eccentricity will never decrease to such an extent at that. So long as the Earth's orbit is decreasing in ellipticity, or in other words, so long as the Sun's average distance from us is increasing, so long also must the Moon's velocity be increasing too. The Moon is at present being accelerated by about 1/400″ of arc every year, which accumulates by arithmetical progression to about 10″ in a century. The result is that our months now are about 1/60th of a second of time shorter than they were 20,000 years ago, and each month is 1/57,000,000th of a second shorter than the last. We need not, however, entertain any fears as to our month ever becoming unduly shortened for our remote descendants, since it is abundantly proved from the fact that the sines and cosines of a circular arc which increase with time can together never be greater than unity, or thus exceed the radius, but must oscillate between zero and unity, however much the time increases, that therefore the major axis of the Moon, and consequently her mean motions are subject only to periodic changes. Thus the length of the month has no tendency in the long run, either to increase or diminish, for the motions of the Moon can do no more than oscillate very slightly from faster to slower, and from slower to faster, in fixed periods of time of about 45,000 years. I may perhaps incidentally remark that the *resistance of ether* (if there be any such) and also the *resistance*

of light have no discoverable effect whatever upon the motions of the Moon. All the complex and subtle motions and sub-motions of the Moon can be entirely and satisfactorily accounted for solely by the universal law of gravitation or the hypothesis of matter attracting directly as the mass and inversely as the square of the distance. I have now tried to put before you, in as clear and concise a manner as I have been able, the principal forces which go to determine the motions of the Moon in space.

At least all these inequality that I have now mentioned, must be taken into due account, before we can predict with any accuracy the position in her orbit which the Moon will assume at any required moment, after of course correcting for refraction, parallax, aberration, &c.

I began by reminding you of the fundamental mathematical laws of motion of two bodies in space. I went on to show that the orbits they describe must be one of the conic sections. I further pointed out that the Moon's orbit under the influence of the Earth's attraction is an ellipse with the Earth in the focus, and stated the amount of its ellipticity. I next brought before your notice the principal modifications of this her normal or primitive elliptical motion, due to the Sun's modifying influence, as the third or disturbing body. This disturbing influence I explained as the difference of attraction either in power or direction, that the Sun exerts upon Earth and Moon at the same time. I showed you that the Sun's disturbing influence can be conveniently resolved into its three rectangular components, namely, the Radial (both positive and negative), the Transversal and the Orthogonal. We saw that these disturbing forces had various effects upon the Moon's motion in space, or upon her position in her orbit at any given moment. The chief of these so-called perturbations or inequalities of the Moon's motions I mentioned as—

1. The Advance of the Moon's apsides.
2. The Retrogression of her nodes.
3. The lengthening of her sidereal period.
4. The change of the Moon's eccentricity or evection.
5. The Moon's Variation or inequalities of her velocity.
6. The Parallactic Inequality.
7. The Annual Equation.
8. The Inequality due to the Earth's elliptical shape, and lastly
9. The Moon's Secular Acceleration.

Observations of the Gegenschien.

By C. V. Raman, M.A.

My object in communicating this note to the Society is chiefly to stimulate the systematic observation of the Zodiacal Light and allied phenomena by the members of the Society who may be situated away from the smoke and glare of the city of Calcutta. Even here, in the midst of Calcutta, I have often had excellent views of the Zodiacal Light before the dawn in the early morning hours when sweeping for comets. From the 9th to the 12th of November last I was at Bankura engaged in working up my observations of Jupiter in company with the Revd. J. Mitchell of Bankura. I put up at the Dâk Bungalow close to Mr. Mitchell's observatory, and got out of bed every morning between 3 and 4 to watch the magnificent cold weather skies. The Zodiacal Light as I saw it then in the east was a glorious phenomenon and most fascinating to watch. The Dâk Bungalow was situated in a retired area, and there were no street lights anywhere that could light up the sky and injure the brilliancy and form of the Zodiacal band of light, which stretched almost right up to the Zenith. To one who had not studied it before, the sight would have been almost a revelation. The distance of the apex from the Sun must have been considerably in excess of 90°.

Looking up on the opposite part of the sky I noticed in the constellation of Aries, a faintly luminous area of fairly small dimensions, probably about 5 degrees each way, which was clearest at a very early hour and gradually became more and more difficult to see till at last it merged into the luminosity of the horizon (I may mention here that the horizon and the part of the sky immediately above it seemed to me brighter than the rest of the non-galactic part of the sky). I noted the position of this area in the constellation and from Klein's atlas I subsequently found the position to be approximately, Dec. 15° *North*, and R. A. 3°. From the Nautical Almanac I find that the position of the Sun on the 10th of November was Dec. 17° *South*, R. A. 15°. It will thus be seen that the position of the area was more or less exactly opposite the Sun on that date. There seems little doubt that what I saw was the Gegenschien. The area of light was some distance away from the Milky Way and quite dissociated from it. From the description of the Milky Way given in Herschel's *Outlines of Astronomy*, it seems fairly

clear that in the particular region of the sky there was no extension of the Milky Way which could have been mistaken for the Gegenschien.

However this may be, there is no doubt that for us in India, we have in the Zodiacal Light and allied phenomena, a splendid field for serious work by amateur astronomers who are situated away from the smoke and glare of the Calcutta sky, and the purpose of this note will be fulfilled if it encourages others to take up the subject. It would, no doubt, be possible to arrange for photometric observation, etc., of the Zodiacal Light.

Lord Rayleigh has shown that a cloud of small particles whose dimensions are small compared with the wave-length of light scatters twice as much light towards the direction of the Sun as in a direction at right angles to it. It seems possible that on the meteoric swarm theory, this result of mathematical theory may explain the special brightness of the Zodiacal band of light in a direction opposite to that of the Sun. If we assume that the greater portion of the cloud of matter outside the Earth's orbit is situated within two or three hundred thousand miles of the Earth, we should see a circular hole in the patch of light corresponding to the shadow of the Earth cast by the Sun. It does not appear that this has ever been observed and possibly the entire illumination is so faint that no detail can be distinguished.

Extracts from Publications.

Snow.

When first observed no snow could be detected upon the planet (Mars), but the north polar zone was enveloped in cloud, as indicated by its bright yellow color, and the pole itself was turned away from us, as shown by the table, at an angle of 10°. The south polar zone was distinctly reddish, as far as the pole itself, and was apparently clear of cloud. August 14 a greenish white spot was seen in the extreme north, extending along the limb some 20°. It was whitish for about 20° farther, and then faded into yellow. The greenish white is probably a contrast effect, and quite different from the greenish grey due to vegetation, which will be noted later. This seems to have been the first appearance of snow. Its diameter was 1,300 miles, assuming it to continue

past the terminator in the same direction to the limb. This would indicate that the snow cap had at this time reached as far south as mean latitude 72°. At the next observation the pole was enveloped in cloud, but by September 2 a slight greenish tint was again seen, and the border was sharply defined against the reddish yellow of the soil. Diameter 1,800 miles. Latitude 65°. On September 13 and 17 small areas of snow were visible through the clouds at the north, and on the latter date it was suspected through the clouds at the south pole as well. The centre of the south polar cap does not coincide with the geographical pole, and the cap itself is more or less permanent. At the time of this observation it would be turned towards us as much as possible.

September 30 the snow was clearly seen at the north as a white patch, measuring 1,700 miles in diameter. Latitude 67°. Vegetation beginning to spring up along its edge or else marshy dark soil, forms a narrow irregular grey band, but not of the blue-black intensity which is seen later in the season as the result of melting. October 12 the north polar regions were again of a yellowish color indicating cloud, but the grey border was more uniform and pronounced than before. Diameter of the snow 2,300 miles. Latitude 58°. October 19, clouds at the limb yellow; over the snow whitish yellow. Diameter of snow 2,100 miles. Latitude 61°. October 30, the northern white spot was at first described as greenish, but an hour later as drab or yellow, and not particularly bright, less bright in fact than a small area near the south pole, which was perhaps really snow. Diameter 2,600 miles. Latitude 53°.

[*Popular Astronomy—January 1914.*]

Crepuscular Rays in the West at Sunrise.

BY CAPT. A. LUCKE, F.R.A.S.

A remarkable display of this not uncommon phenomenon could be witnessed this morning between the hours of 6-30 and 7-30 (mean time, Long. 30° E.). The Sun rose behind a low bank of filmy clouds and its rising presented no abnormal features. In the west the Moon was some 10° above the horizon, setting in a clear sky, except for a quantity of white cirrus clouds from above the Moon to the Zenith. The mirage effects were stronger than usual on the Suez Canal; the air was keen and dry, wind being light from south.

The fan-like rays were suddenly seen below the Moon, spreading out from a point considerably below the horizon to a distance of approximately 17° above it (sextant angles), the dark spaces between the pearly rays distinctly darkening the clouds above mentioned. The rays were irregular in positions and numbers, and their upper edges indistinct in form, the lower being, on the contrary, sharply defined. The general hue of the clear sky in the vicinity appeared a shade between the bright ray and the dark separations, as if, indeed, the dark and the light rays were real and not comparative.

The Moon being full and well up above the horizon, its position marked the centre of the fan, whose rays at 7 hours 10 minutes numbered 14, eight being easily counted to the left, including one of nearly 2° width and a doubtful six to the right, all these last being narrow rays much less bright than the others.

The Sun rose clear, and did not throw any rays in the east, which he frequently does; and these westerly rays, although I have seen them faintly on other occasions, were so strong and persistent that I judge the record of the phenomenon to be of possible interest to the members. The rays were first seen at 6-30 and were lost to view at 7-22.

PORT SAID, EGYPT,

1913, November 15.

[*Journal of the British Astronomical Association for November 1913.*]

Sir Robert Stawell Ball was born in Dublin on July 1, 1840. He was sent to school in England, and became a student of Trinity College, Dublin, in 1857. His university career was one of exceptional brilliancy, and he graduated as gold medallist both in Mathematics and in Experimental Physics. He subsequently worked for some years at Lord Rosse's Observatory at Birr, King's County, where he studied the configurations of nebulæ with the great 6-ft. telescope. In 1867 he became Professor of Applied Mathematics at the Royal College of Science, Dublin, and in 1874 was appointed Andrews Professor of Astronomy in the University of Dublin

and Royal Astronomer of Ireland. This appointment carried with it the Directorship of the Dunsink Observatory, and Ball utilised his opportunities for contributing to the needs of practical astronomy by determinations of stellar parallax (by visual methods of measurement of course, in those days) on a somewhat extensive scale. He also published a series of memoirs on the "Theory of Screws," which brought him a considerable reputation as a mathematician. He was elected a Fellow of the Royal Society in 1873, and was knighted by the Lord Lieutenant of Ireland in 1886. In 1892 he was selected to succeed Adams as Lowdean Professor of Astronomy and Director of the Observatory at Cambridge. On taking up his residence at Cambridge he joined King's College where he was given a Professorial Fellowship. He applied himself with diligence to his professorial duties, and to the organization of the astronomical researches which have been so successfully carried on at the Observatory. But Sir Robert Ball is best known to "the man in the street" as a popular lecturer on astronomy and as a writer of popular books. He was quite one of the pioneers of popular lecturing and even before the days of lantern slides, was able to interest and amuse his audience by the extraordinary charm of his manner and the attractiveness of his wit. His popular books such as "The Story of the Heavens" and companion volumes were remarkably successful and brought him into touch with people of varying grades of intellectual culture. The versatility of the man was one of his great charms. Whether he was officiating as President of the Royal Astronomical Society (which office he held during the years 1897–1899) or was presiding over a dinner of the "T. C. D." Dining Club, he appeared to be equally the right man in the right place. In the same way his formal text-book on "Spherical Astronomy" was as successful in one direction as his "In Starry Realms" was in another. All who knew him (and who did not, either directly or indirectly ?) will feel that they have lost a genial friend, and that by his death a remarkable personality has been withdrawn from our midst. He died at Cambridge on 25th November after a lingering illness.

This Association (of which the deceased had been a member since 1892) was represented at the funeral by Mr. E. B. Knobbel.

[*Journal of the British Astronomical Association for November 1913.*]

Planetary Nebulæ.

By Arthur Prahl, Milwaukee, Wis.

In what follows, short descriptions of some interesting planetary nebulæ are given as they appear in a reflector of 14-in. aperture.

In the first place, the word 'planetary' is a misnomer; it would seem to imply that some of the nebulæ being more condensed than others, are assuming the nature of planets; this certainly is not the case. Indeed some of the so-called planetaries are not even nebulæ, but remote star-clusters. The nebula in Hercules, N.G.C. 6210, may be taken as representative of this class. A power of 700 shows it as a globe floating in space, the edges hazy, and the northern edge brighter than the rest.

The object N.G.C. 6229, in the same constellation, is given as a "large, round, but faint" planetary, discovered by W. Herschel. Whether he saw it so or otherwise, I do not know, but it certainly is not a nebula. With low powers it appears as one, and such I believed it to be for sometime until recently when I observed it several times with powers 450 and 700. The former showed indications of resolution, while the latter power revealed it as a beautiful star-cluster, very dense, with stars of less than the fourteenth magnitude. Had Herschel seen it thus, he would undoubtedly have called it the "richest and most condensed mass of stars in the firmament," an honour which he conferred upon M.80 in Scorpio.

N.G.C. 7027 in Cygnus is described in Webb as being "like an 8·5 magnitude star, about 4″." Schmidt gives it 8″ to 10″, and his estimation is correct. It appears as a double nebula or pair of nebulæ, one about 4″ in diameter, the other about 3″, with about 4″ from centre to centre. Both are clean cut, with no haze, and appear as a double star in the process of evolution.

N.G.C. 6826, in the same constellation, is seen as a nebulous star, or star projected on a nebula which appears as a circular disc of even light superposed upon another larger and fainter disc. A most interesting object.

Another object, N.G.C. 6818 in Sagittarius, is described by Herschel as being of uniform brightness; Rosse and D'Arrest saw in it a darker centre. Under careful observation, the disc is seen to be round; but the darker part is found not to be central, but situated in the preceding half,

of crescent form, and concentric with the edge. The nebula is situated nearly between two stars of about the eleventh magnitude.

N.G.C. 7662 in Andromeda appears as a bright star out of focus with low powers. The higher powers show it as a beautiful annular nebula, round, but with the vacuity eccentric; no trace of Lassell's nucleus and two oval rings. A faint star, 13 magnitude, follows the nebula at about 1′.

The planetary in Aquarius (N.G.C. 7009) is very large, bright, and elliptical, and is a most remarkable object. Lassell saw in it a bright, well-defined ring, while Buffham saw an opening (Webb "Cel. Ob. for Com. Tel," Vol. II, page 24), and Vogel two openings. Such detail is beyond the power of my glass; but at times I have seen the nebula to be of uneven brightness thus faintly indicating the existence of these details. My telescope does, however, show clearly the Saturn-like aspect given the object by the two small attendant nebulæ, of which the preceding is seen to be the smaller, more diffuse, and connected with the large nebula by a faint haze. The following one is the brighter, more definite, and does not seem to be attached like the other.

A small nebula, N.G.C. 2438 in Argo, is situated in the cluster M.46. This appears of even light with low powers; but with a suitable power it is seen to be annular, perfectly formed, with a double star in the centre.

N.G.C. 2022 in Orion presents an even disc of light with no detail.

The large planetary, N.G.C. 3242 in Hydra, appears annular, with two nuclei on opposite sides of the ring. No stars can be seen such as Sesshi thought he saw.

Thus it will be seen that, instead of appearing "planetary," these nebulæ reveal extraordinary details which, instead of tending to solve the problem of their nature, serve to make it more complicated, leaving the observer in deep perplexity, with no hope of a solution.

[*English Mechanic and World of Science—December 19, 1913.*]

Specula-Making.

Amateurs who devote their time to the increasing pursuit of specula-making may like to know of a little device I employ which I have never seen described in "Ours," although I have been a regular reader since 1896, and have searched

through many volumes of earlier years. An ordinary table has to serve me as a workshop bench. In first starting out to make a speculum, I obtained several discs of plate glass, approximately ¾ in. thick, two of 5 in. and two of 6½ in. diameter, from a local glass-merchant at a price of about 3*s*., and this, with 1*s*. worth of carborundum, 3*d*. worth of jeweller's rogue, and sundry small quantities of knife powder, flour emery raided from the kitchen cupboard, has been all that has been required so far. I took an ordinary school slate and cemented the disc to be the tool upon it (starting upon a 5 in. speculum). One of the spare 6½ in. discs, intended to be worked up later, I cemented underneath the slate to prevent flexure. Round the edge of the tool I scratched deeply upon the slate a number of radiating lines as a guide for the eye in insuring a regular slow rotation of the tool, and I cut a groove in one corner of the slate frame so that the carborundum washings could be poured off easily into small glass jars, cementing a cotton reel to the back of the mirror as a handle. I proceeded to work by hand, rough-grinding by carborundum, and working partly by cross strokes and partly by circular. In making the cross strokes it was easy to hold the handle loosely, so that the mirror itself slowly revolved clock-wise, whilst with the left hand I slowly turned the slate with the tool upon it counter-clockwise, allowing a regular number of cross strokes to each of the radiating lines before mentioned and to each interval between them. Working in this way it was easy to swill off the carborundum washings into jars and preserve them for elutriation, and when one had finished an evening's spell, it was only to give the slate and tool a washing under the tap and put them away, leaving the table free for other work if necessary.

I had only one grade of carborundum to work with and chose the finest the local ironmonger could supply. He could not specify which it was. It proved to be a very keen cutting material indeed, quite keen enough for rough-grinding, and in a comparatively short time I had the 5-in. mirror ground to a focus of 50 in. It did not elutriate well, however, as the material seemed to "work down" very little, and the surface when one had done one's best was too coarse to start to polish upon. However, by the use of ordinary knife-powder emery, carefully washed free of grit, and then patiently graded, I was able to get a surface answering the description of being only covered "with a light milky haze, and reflecting light at an angle very well." After polishing with pitch and washed rouge, using the Foucult test in figuring,

making a rough wooden jury-rig tube and stand, and utilising a flat and eyepiece in my possession, I was able to get results on star tests that were immensely encouraging. Although hitherto I had only had experience of small refractors, the perfect achromatism and good dividing power of this first experimental unsilvered mirror made me determine at once to take up reflector construction in earnest, and a most engrossing pastime I have found it. All beginners in this study, like myself, are deeply indebted to the Rev. W. F. A. Ellison for the great generosity he has shown in communicating through the columns of "Ours" the knowledge gained by his large experience in mirror-making and telescopic work generally. Mr. Ellison may be interested to know that I looked up practically every letter he has ever written to the *English Mechanic* before starting on this pleasant pursuit. I believe it is possible for every intelligent amateur to construct for himself, at a small expense, a telescope that will open up new worlds for him, and possibly the use of a slate, as described above, may be found a handy contrivance by those of limited resources.

COVENTRY.

[*English Mechanic and World of Science—December 26, 1913.*]

Professor Turner certainly startled the Royal Astronomical Society with his paper read at this month's meeting, suggesting that sunspots are caused by periodical encounters of Saturn with the Leonid meteor stream, and that these are responsible for several other facts of astronomy which are as yet unexplained. I do not propose to go into further details of the hypothesis, but an excellent summary, by the author himself, will be found in the *Times* of December 13, and commentaries on this in the two succeeding issues of the same paper. I will only say, as a matter of fact, that the reading began with some show of scepticism on the part of the audience; but Professor Turner put his case so convincingly, and brought forward evidence in support from so many quarters, that the Fellows present could not but feel interested, and he sat down amid sincere and loud applause, although as stated in the report in last week's number, it met with criticism on essential points.

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In the Observatory Magazine for December, Mr. Stanley Williams writes about the velocity of the markings known

as the North Equatorial current; that between the years 1879 and 1889 this current continually slowed down, or in other words, the rotation period derived from it increased from 9 hour 50 minutes 30 seconds. From 1889 to 1911 its velocity remained very nearly uniform, but that the observations of this year show that the velocity has begun to increase again. No doubt it is something of this kind that Mr. Phillips has to tell us. It will be interesting to watch whether the velocity of the current returns to its large value of the year 1879.

[*English Mechanic—December 26, 1913.*]

Memoranda for Observers.

[Standard Time of India is adopted in these Memoranda.]

For the month of April 1914.

Sidereal time at 8 p.m.

	H.	M.	S.
April 1st	8	36	25
,, *8th*	9	4	0
,, *15th*	9	31	36
,, *22nd*	9	59	12
,, *29th*	10	26	48

From this table the constellations visible during the evenings in April can be ascertained by a reference to a star chart, as the above hours of sidereal time represent the hours of Right Ascension on the meridian.

Phases of the Moon.

		H.	M.	
April 4th	First Quarter	1	11	A.M.
,, *10th*	Full Moon	6	58	P.M.
,, *17th*	Last Quarter	1	22	,,
,, *25th*	New Moon	4	52	,,

Meteors.

	Radiant. R. A.		Dec.	Character.
April 7th—22nd	210°	—	10°	Slow; fireballs.
,, *18th—23rd*	189°	—	31°	Slow; long.
,, *19th—20th*	201°	+	9°	Slow.
,, *19th—22nd*	271°	+	33°	Swift; brilliant.
,, *30th*	291°	+	59°	Rather slow.

The Planets.

Mercury—Is a morning star throughout the month, and may be seen early in the month rising in Pisces about an hour and a half before the Sun to the south of the Great Square of Pegasus.

Venus—Is an evening star increasing her altitude above the Sun as the month advances. On the 30th she will set about an hour and a half later than the Sun.

Mars—An evening star on his eastward course, travels across Gemini, and will move into Cancer on the 23rd. Position on the 15th R.A. 7·38, Dec. 23° 47′ North.

Jupiter—Is a morning star rising in Capricornus three and a half hours before the Sun at the beginning of the month and five hours at its close. Position on the 15th R.A. 21·20, Dec. 16° 7′ South.

Saturn—An evening star, sets in Taurus about four hours after the Sun at the beginning of the month and two and a half hours after on the 30th. Position on the 15th R.A. 4·53, Dec. 21° 17′ North.

Uranus in Capricornus. Position on the 15th R.A. 20·55, Dec. 18° 1′ South.

Neptune on the line dividing Gemini from Cancer. Position on the 15th R.A. 7·49, Dec. 20° 39′ North.

Notices of the Society.

Election of Members.

The attention of members is invited to Bye-Law No. 14, regulating the election of persons who desire to join the Society. It is hoped that those who are already members will induce others to join. Forms of application can be had from the Secretary.

Change of Addresses.

It is particularly requested that when members change their addresses, they will kindly notify the new address to the Secretary. The omission to do this is likely to cause the loss of the JOURNALS and other communications.

Telegraphic Address.

The address of the Society has been registered at the Telegraph Office, Calcutta. Telegrams should be addressed "Astronomy," Calcutta.

The Library.

A subscription list exists and several members in Calcutta have subscribed and enabled the Council to make a beginning with the Library. Other members outside Calcutta, however, have not, except in one or two cases, yet come forward, and as the Library will be one of the most important adjuncts of the Society, and will be available to members both in and out of Calcutta, those who have not yet done so are invited to help the Society in making progress with this important branch of the work. Suggestions as to useful books for the Library will also be welcomed by the Librarian.

A number of books have already been received and can be borrowed by members in accordance with the Bye-Laws.

The books available can be ascertained from the Assistant Librarian. The reading-room of the Society in the Imperial Secretariat is now opened for the use of members daily from 5 to 7 P.M., except on Wednesdays and holidays, and from 3 to 5 P.M. on Saturdays unless that day is a holiday.

The Journal.

The following charges have been fixed for back numbers of the JOURNAL :—

For members.—Per copy 12 annas ; per volume Rs. 5.

The Star Chart.—As. 12 a copy.

For non-members.—Rs. 1-8 per copy.

The Star Chart.—Rs. 2 a copy.

Subscriptions.

Subscriptions for the current session fell due on 1st October 1913. Those who have not paid in their subscriptions are requested to remit them to the Treasurer without delay.

Papers for Meetings.

It is requested that drawings which accompany papers for reproduction in the JOURNAL may be made with Indian ink on white paper. This will insure a clear reproduction.

List of Instruments.

With a view to enable the Council to obtain a knowledge of the instrumental equipment of the members, it is requested that those members who possess any instrument suitable for astronomical work will kindly send details to the Director of Instruments of its kind, size and power.

Addresses of Officers.

Owing to inconvenience which has arisen from addressing the officers of the Society at their private address, it has been decided to receive communications on the business of the Society in future as follows :—

	To
Money Orders or letters containing money or cheques.	RAI BAHADUR U. L. BANERJEE, Office of the Accountant-General, Bengal, 3, Koila Ghat Street, Calcutta.
All other communications ...	(*Name*) D. N. DUTT, ESQ. (*Designation*) Business Secretary of the Astronomical Society of India, Imperial Secretariat (Treasury) Buildings, Calcutta.

It is requested that communications may be addressed accordingly.

Officers and Council.

FOR THE SEASON 1913-14.

(1) *President* ... ... THE HON'BLE MR. W. A. LEE, F.R.M.S.

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Captain A. M. Urquhart, R.A.

The Journal of the Astronomical Society of India.

VOL. IV.] SESSION 1913-1914. [NO. 5.

Report of the Meeting of the Society held on Tuesday, 24th February 1914.

THE Ordinary Monthly Meeting of the Society was held on Tuesday, the 24th February 1914, in the Imperial Secretariat (Treasury Buildings), at 5-30 P.M. In the absence of the President, Mr. H. G. Tomkins, C.I.E., F.R.A.S., was in the chair.

The minutes of the previous meeting held on Tuesday, the 27th January 1914, were read and confirmed.

The following presents received since the date of the last meeting were announced, and the thanks of the members were accorded to the donors, especially for the exceedingly valuable contribution from the British Astronomical Society in connection with the variable stars. As only a limited number of copies were struck they were sent only to those who were likely to appreciate them and the Chairman hoped that members would make use of the book :—

1. Monthly Notices of the Royal Astronomical Society for December 1913.

2. The Observer's Hand-book for 1914, published by the Royal Astronomical Society of Canada.
3. Journal of the British Astronomical Association for December 1913.
4. Sociedad Astronomica De Barcelona for January 1914.
5. Indian Weather Review—Annual Summary 1912—published by the Meteorological Department of the Government of India.
6. Monthly Weather Review for September 1913, published by the Meteorological Department of the Government of India.
7. Kodaikanal Observatory—Bulletin No. XXXIV.
8. Memoirs of the British Astronomical Association—Appendix to Vols. XV and XVIII.

The election by the Council at their meeting of the 17th February 1914 of Babu Gokul Chund Bural, Calcutta, as a member of the Society, was confirmed.

Chairman.—The first item on the programme is the discussion of Captain Urquhart's paper on the formations on the Moon. Captain Urquhart read his paper at a previous meeting and a long discussion took place which it was impossible to finish that evening as it was very late. I will therefore now ask Captain Urquhart to resume the discussion. (*Captain Urquhart's notes on the objections raised against his paper*).

The Chairman.—There are one or two remarks I would like to make with regard to what Captain Urquhart has said. In the first place may I ask one question as regards the large seas? Captain Urquhart holds that the large seas were formed owing to the impact of a bolide into the surface. He does not quite make it clear how the bolide caused the formation, though he made it quite clear that there was some formation of liquid matter which obliterated the objects on the surface of the plain. What I wish to know is whether Captain Urquhart holds that the bolide by its impact liquefied the surface, or whether it went through the surface thus making an outlet of the internal liquid matter in the Moon.

Captain Urquhart.—My point was that the seas were not caused by bolides at all.

Chairman.—That greatly simplifies the case. I am glad that Captain Urquhart does not hold that these seas are due

to bolides. It seems to me more likely there was some kind of volcanic action. Professor Pickring of America has described the volcanic craters of the Haiwai Islands, and one of them much resembles on a small scale these flat-bottomed formations. The work is in the Library. I think, however, that we may now put the seas out of the question. As regards the size of the other craters, Captain Urquhart mentioned that those who hold the volcanic theory suppose that the vent is 50 miles across to create these formations. I think that in any form of argument it would be wrong to suggest that the vent was anything like 50 miles. It is the formations themselves which are about this size. Naysmith gives a description of a possible method of formation in his book on the Moon. (Black-Board). I don't know that it is a very good one but it has good points about it.

Captain Urquhart.—This method makes out the rings to be ridges on the surface; but I think in the formations I am dealing with, the floor is always lower than the surrounding lunar surface.

Chairman.—I think it is rather doubtful to what extent this is the case. It is very difficult to measure these depths with great accuracy on account of the undefined edges of the shadows. We have nothing on the Moon to correspond to sea level on the Earth, and it is therefore difficult to compare these levels. As regards water on the Moon Captain Urquhart denies any. There may be water in combination with the lunar material, though I do not think that this would be sufficient to cause very large volcanic outbursts. I do not agree, however, that a volcano must depend solely on the presence of water. It is quite conceivable that immense forces in the lunar crust could exist without bringing in the action of water. I do not think that the mere fact that water is absent is sufficient to preclude the presence of large internal forces. Copernicus is a formation on which I have done a lot of work, and I think there is certainly evidence there of internal forces in the star-shaped formations round it. Similarly also with Tycho and several others. I may perhaps briefly mention my own work on the Moon as it has some bearing on this question. The object of my observation was the explanation of the white ray systems and Copernicus was the one on which I spent most time. If we consider the system simply as a formation apart from its albedo, it can be explained on the supposition that an internal force upheaved the crust at that point. After the upheaval there would be a subsidence, and this would cause the formation of

radiating ridges corresponding to the general idea of the rays round these craters. Now comes the question, are the rays elevated at all about the lunar surface? If they are, this supports the theory. After spending 5 or 6 years observing them on every possible occasion, I think no doubt exists that a great many of them at any rate are low elevations above the general surface. This then goes to show that there must have been internal forces far greater than would account merely for the crater cones. Moreover the ridges if formed as I suppose would be lines of weakness in the crust, and would therefore if internal forces existed be places where we might expect to find crater cones and curiously enough we do find them in considerable numbers down the crests of these ridges. I do not wish to put every thing on the Moon down to volcanic forces, but I think there is clear evidence of it having been there on a large scale. How the formations we are considering were built up, I do not think we yet know, but I prefer to look in the direction of forces which we know nature has employed on the Earth and evidences of which we see also in the Moon, rather than go outside our experience at any rate for the present.

Revd. Mr. Ridsdale.—Captain Urquhart will forgive me if I say that the more I think over the matter, the more utterly impossible the theory of Dr. See's which he has so ably advocated appears to me to be. In the first place Captain Urquhart takes for granted that because the Moon is smaller than the Earth that therefore the volcanic force is less there than on the Earth. The volcanic forces, however, are by no means in any proportion to the relative sizes or masses of Earth and Moon. Volcanic force is generated merely within the thin crusts of either body, and therefore bears no proportion to their respective radii. So far from the volcanic force at the Moon's surface being less than that at the Earth's surface, as Captain Urquhart supposes, it was greater owing to the Moon's crust contracting much more rapidly than the Earth's crust, due to the Moon's mass being much smaller and therefore cooling much more quickly. Again, Captain Urquhart makes a difficulty in the matter of the great size of the lunar craters. But there is no difficulty really, because gavity is only $\frac{1}{6}$ × gravity at the Earth's surface. And this fact combined with the other I have just mentioned, *viz.*, that the Moon's volcanic force is actually greater than the Earth, will even more than account mathematically for the great size of the lunar craters. Captain Urquhart now says that as the gravity on the Moon's surface is less than on the Earth, the compression will therefore be less, and therefore

the force of projection will be less. But here again Captain Urquhart is mistaken, since the question of compression has nothing to do with the tract of a bolide when it has once got away from the surface. From that moment it will be only gravity that can affect its velocity and gravity being less at the Moon, both the velocity and distance of the bolide's path will be greater, and hence the craters formed will be greater.

Again the Moon never rotated more rapidly than it does now. For why should it have? It separated from the parent Earth most gently and gradually. It was not shot out from the Earth like a cannon ball, but owing to unstable equilibrium, the Earth-Moon mass was gradually elongated in the plane of its rotation. Two portions in the ratio of 81 : 1 parted company. This being so, the Moon always turned her face towards the Earth. How then was the Earth able to shoot bolides at the back of the Moon, on the side of the Moon that is turned away? For there are certainly craters equally on the further side of the Moon, as can be seen when the Moon is in libration.

Again and this I think is an unanswerable objection to this curious theory of Dr. See's—if the Earth produced craters on the Moon by volcanic bolides, why did not the Moon produce craters on the Earth by her volcanic bolides? Surely Captain Urquhart will not maintain that Vesuvius, for instance, is a lunar bolide.

Lastly, I would point out that all bolides from the Earth which were shot out in any direction not exactly normal to the Earth's surface would make an angle of incidence upon the Moon's surface equal to the angle of projection multiplied by the square root of the ratio of the distances from Earth and Moon to the point between them where attraction would be balanced. And this is equal to the square root of the ratio of their respective masses, or $\sqrt{81} = 9$. Thus according to Dr. See's theory the craters ought to form very sensible ellipses. But they do *not*.

Chairman.—Mr. Ridsdale and Captain Urquhart differ about the rate at which the Moon revolved. But I think Mr. Ridsdale's point could be put another way without touching the question of rate. What about the formations at the North and South Poles of the Moon? These at any rate did not ever appear in the middle of the lunar disc as viewed from the Earth.

Mr. Simmons.—Mr. Simmons said in his opinion Mr. Ridsdale had made a point when he enquired whether Captain Urquhart could cite any case in which bolides had produced the same effects on the Earth which it was claimed they had on the Moon. Those opposed to Captain Urquhart could point for a volcanic formation similar to that on the Moon to the district round Naples, and the Chairman had mentioned another case in the Hawacian Islands. The speaker thought the Chairman, Mr. Tomkins, had not attributed sufficient importance to the factor of shrinkage. Shrinkage had been in operation ever since the Solar system began to condense from the original Nebula out of which it was formed. It was still at work in the Sun, and caused its enormous heat. This led Mr. Simmons to turn to Captain Urquhart's having spoken of Jupiter as a young planet. Jupiter was millions of years older than the Earth, for it broke away from the shrinking Nebula long ago before the Earth did so. (Captain Urquhart interposed that he had referred to the state in which Jupiter is at present, and had not spoken of the planet's origin.) The speaker further considered Captain Urquhart was not justified in assuming that there never had been water, or air, on the Moon. He also could not accept Captain Urquhart's explanation that the absence of any district on the Earth which had been bombarded by the Meteors was satisfactorily explained by denudation, &c. Mr. Simmons in conclusion referred to the relative sizes of craters on the Earth and Moon, and to the circular as opposed to the elliptical form, which latter these lunar craters would have normally assumed if caused by bolides.

Captain Urquhart.—I must reply very briefly to some of the points raised. Mr. Tomkins admits that volcanic forces as we know them do not altogether explain the formations on the Moon, but he attributes such formations as Copernicus to internal forces of some kind. My argument is that the bombardment theory is the only one that satisfactorily accounts for the surface formations as we find them. Even if we admit the great cohesion in the material of the Moon's crust necessary to allow a formation of the size of Copernicus to swell out like a mighty bubble and then collapse, the existence of such tremendous forces in the already dying Moon requires, I think, a stretch of the imagination much greater than any allowed for in the bolide theory.

As regards the Revd. Mr. Ridsdale's objections, I did not mean to suggest that the volcanic forces on the Earth and the Moon would be directly proportionate to their sizes.

What I meant was, that volcanic action on the Moon would probably be less and not greater than that on the Earth ; first owing to the absence of water in any very large quantities on the former, and secondly owing to a much less surface or crust resistance to the exploding force.

Mr. Ridsdale takes for granted that the Moon gently slid away from its parent Earth and has never exposed its " back " to bombardment ; I, on the other hand, maintain that it most probably did revolve faster on its axis than it does now and that we have no valid reason to suppose that it ever formed a part of our Earth.

As to what he considers the unanswerable objection of mutual bombardment, the Moon no doubt did have an occasional shot at the Earth in its younger days, but such shots would never produce a vesuvius, but craters or depressions much deeper than any we find on the Moon, owing to the much greater velocity caused by the Earth's attraction, that is if the bolides escaped destruction in the Earth's atmosphere. But there can be no evidence of such depressions as they are covered by many thicknesses of stratified rocks.

I have already shown that any bolides shot out from the Earth well away from the line of centre would most probably fall back on the Earth, but here again any traces of such must be deep down in the crust, completely obliterated during early geological ages.

Mr. Tomkins allows that the Moon may have revolved faster on its axis in past ages, but he thinks it impossible that the Moon's poles could ever have been exposed to bombardment from the Earth for they never shift. In a recent issue of the Society's Journal appeared an article by Mr. Hart on the " Shifting Ecliptic," in which he showed how the Earth's poles in past ages pointed towards the Sun and will do so again in the distant future. Is it then impossible that the Moon may have similarly moved in relation to the Earth ?

My previous remarks cover Mr. Simmon's objections. I quite admit that volcanic action took place on the Moon (and we have evidence of that in the crater cones), also that there must have been water present though not in any very large quantities, and no doubt a gaseous envelope, however tenous, must have surrounded the Moon in the earlier stages of its cooling. Both Mr. Simmons and Mr. Ridsdale do not seem to realise that it is not the relative sizes of craters on the Earth and the Moon that constitute the main difficulty, but their actual structure. The " craters " on the Moon are depressions

in the surface (the floor in many cases being several thousand feet below the surrounding surface), whereas volcanic action forms a cone with a crater on top.

The meeting was then adjourned.

Reply to criticism on Captain Urquhart's paper on the Moon.

MR. TOMKINS' objections :—

(*a*) That the seas are almost similar in every respect to large flat-bottomed craters; and that, if bombardment is responsible for the latter, it must also have produced the seas.

The reply to this is—

(1) That we should expect large depressions on a globe to take a more or less circular formation.

(2) That the borders of the seas do not show a continuous rampart of a similar form to that surrounding the ring formations.

(3) That the surface of the seas show numerous relics of the earlier surface formations (*vide* Elger's "The Moon," p. 3), which shows that the older surface must have been depressed, probably owing to natural shrinkage of the globe, and its formations more or less obliterated by the overflow of the liquid interior. There are no signs of an earlier surface formation left in any of the large walled plains.

(*b*) That the great size of the bolides required to produce such formations makes it very doubtful if the Earth could ever have thrown them out, and that the supporters of the meteoric theory usually go outside the Earth to the Solar system for their meteorites.

I have already shown that there are at least two serious objections to the bolides having come from outside the Earth-Moon system :—(1) Such bolides would very seldom strike the Moon normally to its surface. (2) Their striking velocity would be much too great to produce formations of the kind we find on the Moon's surface.

The only objection that seems to me to have any weight is the doubt whether the Earth was capable of throwing out such huge masses. I have already shown that the size of the craters would be many times the size of the missiles which

produced them. Probably a mass of about 10 miles in diameter would be the utmost limit required for the largest crater. The upholders of the volcanic theory have no hesitation in allowing a volcanic vent of any thing up to 100 miles on a comparatively small globe like the Moon, while they would consider one of a few miles diameter impossible on the Earth. As to the idea that the forces necessary to shoot out such masses would wreck the Earth, what about the recent volcanic outbursts in Japan, when masses of rock weighing many tons were thrown thousands of feet into the air, falling many miles away from the volcano, yet these disturbances did not even affect the seismometers over here.

If such eruptions take place on the Earth in its old age, how much greater must they have been in its fiery youth? And what about the evidence of activity in the more youthful members of the Solar family, *e.g.*, Jupiter and Saturn?

(*c*) "That the chains of inosculating craters on the Moon could not be due to bombardment." I do not maintain that these were so formed, I believe that many selenographers (*vide* Elger's "The Moon," p. 17) hold that these are actually raised above the surface and are of the nature of volcanic cones. These crater cones are evidence of former volcanic activity, and show that volcanic energy produces on the Moon similar formations to what it does on the Earth.

The absence of water in any large quantities, as far as can be seen on the Moon, is against the idea of great volcanic activity, and where volcanic activity exists it gives a similar result to what we find on the Earth. If nature worked as quietly and smoothly as is imagined during the earlier ages of the Earth, why should it result in such violent convulsions on the Moon?

The idea put forward by Mr. Ridsdale that the smaller force of gravity on the Moon would account for such widely differing results of volcanic action, seems to me untenable, and I do not think there is any foundation for it, either on mathematical or physical grounds. We know that the effect of an explosive depends largely on the resistance which it has to overcome, and the smaller the force of gravity on the surface of a globe the less the eruptive force which would be generated.

Mr. Raman objected that the Moon having once been a part of the Earth must also necessarily have retained its volcanic nature, and that hence no other explanation is required of the surface formations. Even supposing that the Moon was once a part of the Earth (which I don't at all

admit), its volcanic activity would result in similar formations to what we find on the Earth, and I have already pointed out that we have evidence of this in the "crater cones." But this does not explain the huge *depressions*. If the volcanic theory could explain all the formations on the Moon there would be no necessity to search for other explanations. The formations are exactly of the kind that would be produced by masses of matter falling on the surface of the Moon, and the direction of impact and the regular velocity could only have resulted from masses thrown out by the Earth.

Mr. Simmons' objections do not apply to the bombardment theory as I have put it forward. There are no volcanoes on the Moon similar to what we find on the Earth with the exception of the comparatively small "crater cones."

The comparative (and largely imaginative) pictures of the district round Naples and a similar region on the Moon, look all right on paper at a casual glance, but unfortunately the most important feature is absent on the Moon—there is no vesuvius!

The fact that the fragments of a bolide following on the Earth arrange themselves in the form of an ellipse, does not apply to the ring formations on the Moon. There is no atmosphere to explode the bolides. Besides the depressions must have been produced by masses which arrived more or less intact, and not by meteoric dust.

A. M. URQUHART.

Correspondence.

10, QUEEN'S ROAD, BOMBAY,
The 1st March 1914.

DEAR SIR,

I have read Captain Urquhart's lectures, reproduced in the June 1913 and January 1914 numbers of the Journal, with much interest. It has occurred to me that the craters may be accounted for in the following way:—

We know that the Moon is not heavy enough to retain permanently any gases. Hence, at no stage of its existence can it have had an atmosphere of appreciable density. That is to say, its surface must always have been exposed, with hardly any covering, to the cold of space.

We may assume that when the Moon was torn away from the Earth under the action of tidal forces, it was liquid or viscous in compostion. Its surface must very quickly have become solid or nearly so in contact with a temperature approaching absolute zero.

Chemical forces acting in the interior must have given off quantities of gas, which would naturally seek the surface. Is it not possible that the tension of the solid surface would have caused very large quantities of gas gradually to accumulate just below it in the shape of enormous bubbles ?

Presently the pressure of the gas would overcome the surface tension, and the bubble would burst ; some disruption of the surface, the temperature of which would momentarily be raised, would take place, and from what we know of the action of bubbles, the portions thrown upwards would settle and form craters.

A lunar crater is therefore, by this theory, the product of one single explosive action and not of eruptions carried on at intervals through a long period of time, as in the case of earthly volcanoes.

The lunar surface would also crack as it contracted under the influence of falling temperature, and we can conceive of the molten interior pouring through the cracks and forming the *maria*.

I am aware that the above theory is largely conjecture ; but I do not remember ever seeing it set forth, and I think it is worthy of consideration.

Yours faithfully,

F. C. MOLESWORTH.

THE EDITOR,

THE JOURNAL OF THE ASTRONOMICAL SOCIETY OF INDIA.

8/2, HASTINGS STREET, CALCUTTA,

The 25th February 1914.

DEAR MR. RAMAN,

Herewith a copy of the telegram I received from Mr. Hart on Monday, 16th current :—

Mercury now visible here ; brilliant as Polaris ; sets hour after Sun. Mira Ceti now attained fully fourth magnitude. (*Hart.*)

The days intervening between receipt of the telegram, and Friday last, were cloudy, if not overcast altogether. We

saw Mercury on Friday and Saturday, without, and on Sunday evening through a telescope, when it showed as a crescent. I have not looked for it since, but my sister observed it on Monday evening. It will be visible till the 10th proximo, but you will now be getting a young and waxing Moon in the early evening. I should *think* we saw Mercury about 12° to 16° above the horizon ; but I am *not* sure of the altitudes.

I have not looked for Mira which is now very much in the western sky.

Yours sincerely,

W. J. SIMMONS.

C. V. RAMAN, Esq.

Note by Mr. Raman.

Mr. Mitchell writes from Bankura on date, 22nd February, "Mercury is now easily visible ½ Moon." I saw Mercury myself very easily a little after sunset on the 25th, and it seemed to me that it was brighter than Polaris which was just visible at the time. My 2⅞″ telescope showed the disc clearly, but the image was very unsteady.

C. V. R.

Extracts from Publications.

Jupiter.

Mr. Phillips replied that it was June and July 1913. The weather, fortunately, during the latter part of the summer, was unusually favourable, so that, although the planet was badly placed, they were able at Ashtead to get a large number of observations of these dark protuberances and white egg-shaped markings. He found that the equatorial current, or at least its northern part, was this year (1913) drifting at an unusually rapid rate. It was interesting to compare the velocity in 1913 with that of former years, and he had made a slide showing the rotation periods of equatorial spots from 1879 to 1913.

The number of spots made use of in some of the earlier determinations was rather small, but he thought the main results were reliable. From the slide it was seen that whereas

the rotation period in 1879 was 9 hours 49 minutes 59 seconds, during the next ten years the velocity steadily diminished. By 1889 the period was fully half a minute longer, or 9 hours 50 minutes 30 seconds ±, and throughout the next 20 years or so it oscillated between certain limits about this value with a slight diminution about 1900. He had no reliable results so far for 1912, but in 1913 the north equatorial spots before described showed an accelerated motion which was quite extraordinary. In fact, the value of the rotation period dropped to about 9 hours 50 minutes 12 seconds, practically what it was 30 years ago, and from the middle of August to the beginning of November it still further diminished to 9 hours 50 minutes 10 seconds. It was unfortunate that he had not got any results for the southern part of the current in 1913, but they might assume, perhaps, that the movement of the north equatorial spots represented more or less accurately the equatorial current as a whole in 1913. It would be interesting to see whether the accleration was maintained, and also whether the curve repeated itself. He supposed he could hardly expect to see it repeated in his lifetime, but he would like to see it fairly on its way.

[*Journal of the British Astronomical Association for December 1913.*]

Silvering Mirrors.

There is no lack of formulæ for the silvering of glass; but the technical difficulties which require to be overcome in the production of a silver coating of good quality, permanence, and adherence are as a rule very considerable. Many years' experience with the various recipes has shown that it is an easy matter to obtain perfect silvering on blown glass; but that the difficulties are encountered when dealing with surfaces of polished glass, particularly when these latter are silvered again and again. This is especially the case when the silvered surface is required to reflect satisfactorily from the coated side. Moreover, difficulties are likewise met with in polishing coatings of metallic silver, which are obtained in the chemical way without the required degree of reflective surface. The film of silver is extremely soft, and it is scarcely ever possible to subject it to after-polishing without scratching it. Therefore, it is highly necessary that a process of silvering should be used which yields a highly-reflecting surface without any after-treatment, or, at any rate, reduces such after-treatment to the minimum. Modern methods of

silvering, especially those with formaldehyde, yield fine, even, and reflective surfaces; but the processes are most unreliable, particularly in the case of surfaces which have been frequently polished. For these they are practically useless, and altogether so when regard has to be paid to the even absorption by the silver film, as when preparing filters for ultra-violet light. Such silver coatings are invariably cloudy, as also are those prepared with Rochelle salt.

In attempts to prepare silver surfaces of satisfactory quality and permanence I have employed a process which I have worked out from the data of Professor Gehrke in conjunction with Dr. B. Seegert. It is one which is allied to the old Martin process, and providing that certain precautions are observed, yields excellent results. The method is exceedingly simple to carry. It does not call for any scrupulous purity of the chemicals, particularly of the caustic alkali and ammonia, whilst its results, as regards good reflective power, adherence, and permanence, are excellent even under unfavourable conditions. Moreover, the cleaning of the glass when this process is used, is not of such immense importance as it is in others, and there is not the necessity to keep the surface to be silvered under water, thereby increasing the difficulty of manipulation, and at the same time injuring the surface polish. The process in the form in which it is at present used is described below.

Cleaning the Glass Surface.

Any silver coating perviously on the glass is cleaned off with dilute nitric acid with aid of cotton-wool. The glass is then rinsed, and any traces of nitric acid removed with weak ammonia. The slightest trace of nitric acid on the surface or edges of the glass gives rise subsequently in the process to the most serious difficulties, *e.g.*, the silver film is liable to undergo partial solution locally. The glass, after this preparation, is dried with a linen cloth, and the cleaning process proper then carried out. This is done very simply as follows:— Equal parts of spirit of wine and commercial strong ammonia are mixed together and enough powdered inpalpable precipitated chalk added to form a thick mixture on shaking up. A few drops of this mixture are poured on to the glass, and rubbed over the whole surface quickly and evenly with cotton-wool free from grease. Before the mixture has quite dried off, a second tuft of cotton-wool is used with a quick, circular movement to remove the residue of the cleaning

mixture, and as soon as the last trace has disappeared further rubbing is discontinued. Long rubbing with cotton-wool which has become dry tends to unevenness of the silver deposit. In the above manipulation it is important to use cotton-wool which is perfectly free from any trace of fat or grease, and the fingers should be in the same condition, for which purpose they are rubbed over, before commencing the work, with a little of a mixture of spirit and ammonia. The glass surface is now ready for silvering, and should not be dusted, nor, of course, touched. The silvering is best done immediately, or after an hour or so; plates which are kept for a longer time after cleaning are found to silver badly.

Preparing the Silvering Mixture.

The silvering solution is prepared from the following two stock solutions:—

A.	Silver nitrate	30 gm. ...	... 1 oz.
	Water ...	900 c.c. ...	... 30 oz.
B.	Caustic potash	20 gm. ...	... ½ oz.—90 gr.
	Water ...	900 c.c. ...	... 30 oz.

To prepare the mixture 750 cc. (26¼ oz.) of solution A is placed in a capacious bottle, and ammonia added to it until it is just decolourised. It is most important to avoid any excess of ammonia. It is best to ascertain the strength of the ammonia, and from this to add straight away nine-tenths of the whole, adding the remaining tenth drop by drop, with constant shaking until the exact condition is secured. This colourless solution having been prepared, the whole of solution No. 2 is now added very slowly, with constant shaking in order to avoid the formation of a coarse precipitate. There results a deep brown opalescent liquid, which is constantly shaken while further adding amonia drop by drop, until the point is reached at which a bright solution is temporarily obtained. Here also any excess must be carefully guarded against. The solution should be perfectly clear, but without excess of ammonia, and there is now added to it, with constant stirring, the remaining 150 cc. (5¼ oz.) of solution A, the addition of which produces a strongly opalescent brownish or yellowish liquid, which is at once filtered, and is then ready for use in silvering.

It is inadvisable to make up larger quantities of the silver solution than that given above. After an hour or two small quantities of a black metallic-looking precipitate begin to deposit, first forming as a crust on the surface, and then falling to the bottom. They do not affect the silvering so long as the solution is drawn off free from deposit, and old solutions work just as well as fresh. Experience has, however, shown that the storage of the silver solution is not without danger. In one instance we experienced a somewhat violent explosion of some litres of the mixture, which broke the containing bottle into small fragments. In other cases, where attempts were made to ascertain the properties of the silver solution, it was not found possible to provoke the explosion by artificial means. Even the black precipitate was found non-explosive; but, nevertheless, it is well to observe due care in its use.

As a reducing agent one can use either the usual inverted cane-sugar or grape-sugar solution prepared from pure grape-sugar. The inverted cane-sugar solution is prepared as follows :—

C.	Lump sugar ...	...	25 gm. 385 gr.
	Tartaric acid ...	...	3 gm. 45 gr.

These are dissolved in 250 cc. (8¾ oz.) of water, and kept at boiling point for about 10 or 15 minutes until inverted, cooled, and 50 cc. (1¾ oz.) of alcohol added. The solution is then diluted with water to 500 cc. (17½ oz.). In place of it, a 5 per cent. solution of grape-sugar may be used with exactly the same effect.

The quantity of solution of the reducing agent in comparison with the silver solution is of some effect upon the result. If we use 10 parts of silver solution to 1 part of reducing solution, the process proceeds quickly, but the mirror is not of clean bright surface, and the deposit adheres badly. Larger quantities of reducing agent (about 30 per cent. of the silver solution) yield the best, most permanent, and brightest coatings. If the proportion of reducing agent be made still greater, the silvering then proceeds slowly; the coating is not such a fine surface, but extremely even by transmitted light. This last form of the process is very suitable when making filters for ultra-violet light; but the one given above is the best when silvering glass for use as a reflector.

Manipulation in Silvering.

The temperature of the silvering mixture is not of very great effect in the process; but the glass to be coated should not be colder than the solution. If it is warmer, all the better. The silvering takes place best when the surface to be coated is flooded with the silvering mixture immediately the latter has been compounded. Placing the surface to be silvered downwards gives bad results. It is best to use glass dishes in which the glass to be silvered is simply laid or is fastened to the bottom with two or three bits of wax. The silvering solution must cover the surface to be silvered to the depth of at least 8 mm. to 10 mm. (1-3rd to 2-5ths of an inch).

During the silvering process (which should not be carried out in sunlight) the dish is vigorously rocked continuously. The silvering solution speedily becomes golden yellow in colour, and after from 20 seconds to 30 seconds begins to deposit silver. If all has been done correctly, one sees then that the clean surface of the glass first assumes a beautiful sky colour, quickly assuming a silver grey tone and then a metallic surface. The silvering is allowed to proceed with constant rocking, until there deposit on the silvered coating tiny silver bodules of about the size of a pin's head, which grow from second to second and finally cover the surface with a grey coating resembling leather. But before this point is reached, the operation must be instantly stopped. The correct point requires to be learnt by experience. Silvering for too short a time gives a coating which is readily injured, whilst if carried out for too long a time the surface is dirty and of poor reflecting power. The silvering process is stopped by pouring off the solution quickly, and cleaning the silvered surface with distilled water, which can be sprinkled over it in a fairly strong stream. The silver adhering to the surface is thus removed as far as possible by sprinkling with distilled water, and the plate is then immersed in distilled water, removed without touching the surface, and a large tuft of cotton-wool wetted with distilled water carefully used over the silvered surface with light but gradually increasing pressure. The cotton-wool must on no account be too dry. It will be found after using it for a few minutes that the water is repelled by the silver surface, and as soon as this is the case over the whole of the plate from end to end, the plate is laid film upwards on a solid support, and the last traces of water removed by means of a sheet of filter-paper gently applied with the hand. The excellent adherence of the film enables all these operations to be carried out without risk.

After drying off the last traces of water, the surface should be perfectly uniform, and of fine reflecting power. For most purposes, it is ready for use without further treatment. As a rule, there is a delicate film of a bluish colour adhering to the surface. It appears to consist of finely-divided silver, but is of no disadvantage for most purposes. To remove it, which is necessary only when the silvered surface is to be used from the front, a clean tampon of mocha leather is taken and fastened over a pad of cotton-wool. The leather should be absolutely free from grease. After a few passages of the leather across the surface, with fair pressure, the silver coating becomes perfect, and obtains the maximum of reflecting power. It is very seldom that small fractures are produced by this operation; but they are never of such depth that they can be seen in diffused daylight, but are observable only in sunlight.

Mirrors prepared by the above described process retain their properties in pure air for an astonishing length of time longer than those prepared by most other processes. They are, of course, extremely sensitive to hydrogen sulphide; but they can be kept protected for months against the action of this gas if they are wrapped in paper impregnated with lead acetate, or stored in a box with the lid covered with lead-acetate paper. When in course of time the mirror becomes tarnished by sulphade vapour, it is best to silver it afresh. It is difficult to clean up the tarnished surface. Mocha leather so used removes a part of the discolouration, but is apt to impair the mirror surface. An attempt to clean up the surface by use of a tuft of wood soaked in potassium cyanide solution was found to have the drawback of dissolving the silver deposits in parts. Dust which falls on the surface can, however, always be removed without danger with the leather.—(*Dr. A. Miethe.*)

[*English Mechanic and World of Science—January 9, 1914.*]

The Study of the Stars.

There is no department of Astronomy which is now receiving greater attention than the study of the spectra of the stars. Dr. Henry Draper was the first to photograph the lines in a stellar spectrum, although Sir William Huggins had already obtained a mark from the spectrum of Sirius, and later was the first to publish his results in successfully

photographing steller spectra. The untimely death of Dr. Draper, in the midst of his work, led to the establishment at Harvard of the Henry Draper Memorial. For nearly thirty years Mrs. Draper has maintained an active interest in this work. By placing a large prism over the objective of a telescope, the light of all the brighter stars in the field is spread out into spectra, so that instead of photographing the spectrum of one star at a time, as with a slit spectroscope, as many as a thousand have sometimes been taken on a single plate. Such photographs, covering the entire sky, have been taken with the two 8-inch doublets already mentioned. A study of the spectra thus obtained enabled Mrs. Fleming to discover many hundred objects whose spectra are peculiar. Among them may be mentioned 10 of the 19 new stars known to have appeared during the years in which she was engaged in this work, while 5 of the others were also found at Harvard by other observers. She discovered more than 200 variable stars, 91 out of the 108 stars of the very peculiar fifth type, and showed that these objects occurred only very near the central line of the Milky Way. During the last two or three years a great demand has arisen for the class of spectrum of large numbers of stars. The Harvard photographs show the class of spectrum of nearly two hundred thousand stars. Miss Cannon has, accordingly, undertaken to prepare a catalogue of these objects, with the result that she has already classified about one hundred and fifteen thousand spectra, covering more than one half of the sky. The work is progressing at the rate of five thousand stars monthly, and the results will fill seven of the large quarto Annals of the Harvard Observatory. The organization of this work has required the most careful application of the principles of "scientific management."

[*Popular Astronomy—February 1914.*]

Jupiter 1913.

RED SPOT.

The red spot was seen here first on April 6, already well advanced in the dark region of the S. Tropical Disturbance. Its shape has been strikingly like a dirigible balloon with pointed ends. Its length (probably on account of the pointed extremities showing to greater advantage against their present dark background) has been somewhat longer than

during the former apparition. The mean of measures on seven nights is 35°.60 ± 2° as against 26°·3 last year. Its color has been white, scarcely distinguishable from the color of the zone bounding (p and F) the disturbance. Up to the latter part of June the surface of the disturbed area has been almost uniformly dark whenever seen, except a faint brightening, with vague configuration following the RS. This, early in July, became concentrated in a small white spot nf the RS. which with the white portions immediately following streamed out in a sf direction, suggesting very strongly a drift from the more central regions toward a narrow channel between the RS. and the equatorial zone bordering it on the north. I could never be sure of any passage of material through the channel. The configuration was first sketched June 17 as removed some little distance from the RS., again July 3 as having advanced considerably, and being involved in the space between the RS. and the zone to the N. Its color had become quite brilliant. At first it showed an unbroken line with its front brightest and quite conspicuous, but by August 25 it had broken up into at least four separate little spots that continued in the same line. The front spot at this time was almost abreast the centre of the spot. It is this steady advance that causes us to suspect that in some quiet way the material has been conveyed to the preceding side of the RS., as the general material of the belt drifts past. The above described appearance was seen every night with one curious exception. On the 5th of August between 10 and 11, occurs the following entry. "The white spot just f the RS. cannot be seen : it seems to have disappeared." The RS. was then in full view with a quality of seeing rated 9-8 on a scale of 10. A peculiarity in the shape of the RS was seen in the shape of a very slight concavity on the nf side where it came into contiguity with the white mass just mentioned.

[*Popular Astronomy—February 1914.*]

A Wrong Attitude in Amateur Astronomy.

No doubt all amateurs, in taking up astronomy, take it up originally and primarily for pleasure, recreation and interest. This is natural and to be expected. Astronomy should not, however, even if studied at first for any of the aforesaid reasons, remain to the amateur who is sufficiently advanced

and experienced, merely a means of obtaining personal pleasure; it should contain, even for him, a greater and more dignified signification. Yet how many amateurs are there who are content simply to entertain themselves and their friends with the telescope? I regret to say that there are too many. Just recently I had an experience with an amateur that may be of interest to relate here. I had occasion, upon knowing previously, that the gentlemen in question was one who might be called an amateur astronomer, and was provided with both a telescopic and a photographic outfit, to invite him to join the Society for Practical Astronomy, and particularly our Photographic Section (inasmuch as he was in a position to do photographic work so well). He replied rather dryly to my invitation that he was one of those persons who do not care to join scientific societies, as he did not have the time to contribute anything in the way of written articles, but he would feel, if he joined the S.P.A., as though it were his duty to do something in that line. I endeavoured to explain to him that such would not be expected if he did not have the time, and if he would send in the results of his work to the Director of the Photographic Section, the Director would gladly attend to the proper utilization and publication of them for him. He told me that he would consider the matter, and the result of the conversation was, as might be expected from the beginning, that he preferred to remain alone and cultivate astronomy for his own pleasure and amusement. Upon inquiry, I learned that this gentleman has a 4-inch refractor, permanently mounted under a revolving dome, and in addition to this, a 4-inch photographic lens by Brashear an outfit which any amateur might prize and justly be proud of, and which if, in the proper hands, could yield results of almost unlimited worth in more than one branch of observation. I cite this case merely as one typical of many that I have personally encountered since I began, some years ago, to do my part in the movement to unite amateur astronomers and incite them to work and to observe systematically. I may state that the gentleman alluded to is not by himself, but is representative of a singularly large number of amateur astronomers all over this country who, though they are able and willing to take the pains and spend the money required to build up a rare astronomical equipment, yet, at the same time, are unwilling to use that outfit in such way that it shall be of utility for anything outside of their own personal entertainment. I know of several such cases in one city, and know of a certain amateur who has a fine observatory, a

magnificent large refractor with a varied stock of eye-pieces and other accessories, a micrometer, a camera, a spectroscope, in short, everything that one could want an equipment that would indeed be a credit to any college or university, who probably has never made or published a single observation of scientific value, although he has been interested in astronomy, I understand, most of his life!

[*Popular Astronomy—February 1914.*]

Memoranda for Observers.

[Standard Time of India is adopted in these Memoranda.]

For the month of May 1914.

Sidereal time at 8 p.m.

		H.	M.	S.
May	*1st*	10	34	41
,,	*8th*	11	2	17
,,	*15th*	11	29	53
,,	*22nd*	11	57	29
,,	*29th*	12	25	5

From this table the constellations visible during the evenings in May can be ascertained by a reference to a star chart, as the above hours or sidereal time represent the hours of Right Ascension on the meridian.

Phases of the Moon.

			H.	M.	
May	*3rd* First Quarter	...	11	59	A.M.
,,	*10th* Full Moon	...	3	1	,,
,,	*17th* Last Quarter	...	3	42	,,
,,	*25th* New Moon	...	8	5	,,

Meteors.

		Radiant. R.A.	Dec.	Character.
May	*1st—8th*	338°	—2°	Swift; streaks; brilliant.
,,	*2nd—13th*	245°	+ 3°	Slow; bright.
,,	*18th—26th*	246°	+29°	Swift; white.
,,	*29th—June 4th*	333°	+27°	Swift; streaks.
May-June		353°	+39°	Swift; streaks.
May-June-July		252°	—21°	Slow; trains.

The Planets.

Mercury—Is a morning star until the 17th. When he will be in superior conjunction with the Sun, and then become an evening star until the middle of July. He will be too near to the Sun to be visible at any time during the month.

Venus—Is an evening star and sets about an hour and a quarter after the Sun at the beginning of the month, and about two hours after at its close.

Mars—Is also an evening star, setting in Cancer about five hours later than the Sun throughout the month. Position on the 15th R.A. 8·39, Dec. 20° 12′ North.

Jupiter—A morning star, rises in Capricornus about five hours before the Sun on the 1st and nearly seven hours after on the 31st. He will be in quadrature with the Sun on the 12th. Position on the 15th R.A. 21·35, Dec. 15° 5′ South.

Saturn—Is an evening star, setting in Taurus about two hours after the Sun on the 1st and three quarters of an hour after on the 31st. Position on the 15th R.A. 5·8, Dec. 21° 42′ North.

Uranus in Capricornus. Position on the 15th R.A. 20·57, Dec. 17° 55′ South.

Neptune in Cancer. Position on the 15th R.A. 7·51, Dec. 20° 35′ North.

Notices of the Society.

Election of Members.

The attention of members is invited to Bye-Law No. 14, regulating the election of persons who desire to join the Society. It is hoped that those who are already members will induce others to join. Forms of application can be had from the Secretary.

Change of Addresses.

It is particularly requested that when members change their addresses, they will kindly notify the new address to the Secretary. The omission to do this is likely to cause the loss of the JOURNALS and other communications.

Telegraphic Address.

The address of the Society has been registered at the Telegraph Office, Calcutta. Telegrams should be addressed "Astronomy," Calcutta.

The Library.

A subscription list exists and several members in Calcutta have subscribed and enabled the Council to make a beginning with the Library. Other members outside Calcutta, however, have not, except in one or two cases, yet come forward, and as the Library will be one of the most important adjuncts of the Society, and will be available to members both in and out of Calcutta, those who have not yet done so are invited to help the Society in making progress with this important branch of the work. Suggestions as to useful books for the Library will also be welcomed by the Librarian.

A number of books have already been received and can be borrowed by members in accordance with the Bye-Laws.

The books available can be ascertained from the Assistant Librarian. The reading-room of the Society in the Imperial Secretariat is now opened for the use of members daily from 5 to 7 P.M., except on Wednesdays and holidays, and from 3 to 5 P.M. on Saturdays unless that day is a holiday.

The Journal.

The following charges have been fixed for back numbers of the JOURNAL:—

For members.—Per copy 12 annas; per volume Rs. 5.

The Star Chart.—As. 12 a copy.

For non-members.—Rs. 1-8 per copy.

The Star Chart.—Rs. 2 a copy.

Subscriptions.

Subscriptions for the current session fell due on 1st October 1913. Those who have not paid in their subscriptions are requested to remit them to the Treasurer without delay.

Papers for Meetings.

It is requested that drawings which accompany papers for reproduction in the JOURNAL may be made with Indian ink on white paper. This will insure a clear reproduction.

List of Instruments.

With a view to enable the Council to obtain a knowledge of the instrumental equipment of the members, it is requested that those members who possess any instrument suitable for astronomical work will kindly send details to the Director of Instruments of its kind, size and power.

Addresses of Officers.

Owing to inconvenience which has arisen from addressing the officers of the Society at their private address, it has been decided to receive communications on the business of the Society in future as follows :—

	To
Money Orders or letters containing money or cheques.	RAI BAHADUR U. L. BANERJEE, Office of the Accountant-General, Bengal, 3, Koila Ghat Street, Calcutta.
All other communications ...	(*Name*) D. N. DUTT, ESQ. (*Designation*) Business Secretary of the Astronomical Society of India, Imperial Secretariat (Treasury) Buildings, Calcutta.

It is requested that communications may be addressed accordingly.

Officers and Council.

FOR THE SEASON 1913-14.

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The Journal of the Astronomical Society of India.

VOL. IV.] SESSION 1913-1914. [No. 6.

Report of the Meeting of the Society held on Tuesday, 31st March 1914.

THE Ordinary Monthly Meeting of the Society was held on Tuesday, the 31st March 1914, in the Imperial Secretariat (Treasury Buildings), at 5-30 P.M. The President, the Hon'ble Mr. W. A. Lee, F.R.M.S., was in the chair.

The minutes of the previous meeting held on Tuesday, the 24th February 1914, were read and confirmed.

The following presents received since the date of the last meeting were announced, and the thanks of the members were accorded to the donors :—

1. Monthly Notices of the Royal Astronomical Society, Vol. LXXIV, No. 3.
2. The South African Journal of Science, Vol. X, Nos. 3 and 4.
3. Journal of the Astronomical Society of Canada, Vol. VII, No. 6.

4. Annales DeL'Observatoire, Royal De Bilgique, 1913.
5. Journal of the British Astronomical Association, Vol. XXIV, No. 4.
6. Sociedad Astronomica De Barcelona, Vol. IV, Nos. 37 and 38.
7. Monthly Weather Review for October 1913, published by the Meteorological Department of the Government of India.
8. Kodaikanal Observatory—Bulletin No. XXXVI.
9. Memoirs of the British Astronomical Association, Vol. XXIV, Part IV.

The election by the Council at their meeting of the 17th March 1914 of Mr. R. S. Lister, Ghum, as a member of the Society, was confirmed.

President.—The next item is a paper by Mr. A. B. Chatwood on "An approximate method of computing precession in certain cases." I am afraid this is hardly a paper to be read in detail at the meeting as it is mostly composed of mathematical formulæ and tables of figures. The purport of this paper is a convenient method of computing precession for the purpose of correcting the places of stars in photographs of 2° square, such as are taken for the Great Star Map on which Mr. Chatwood gave us such an interesting lecture. It will be published in the Society's Journal and members will then have an opportunity of studying it.

President.—The next item is a paper by Mr. Raman on "Saturn in a small telescope." (*Paper.*)

President.—I am sure we are very much indebted to Mr. Raman for his demonstration that the visibility of a dark gap like Cassini's division is not exactly the same as visibility of a separation between two points of light. For the separation of two points of light, such as a double star, a rough rule is to divide 4½ in. by the aperture in inches, so for Mr. Raman's telescope 1½ in. is about the limit of separability. This is not a question of sight but of what a telescope of a given size can do. Mr. Raman has explained that a dark gap between bands of light is not exactly the same thing as a space between points of light, and that therefore you may see a dark gap between bands of light, even when it is narrower than the limit of visibility of a space between points of light. You will not see it as an absolutely black strip, but as a difference of illumination, a darker line.

President.—Would any member like to make any remarks on Mr. Raman's paper ?

President.—The next item is a paper by Revd. Mr. Ridsdale on "Some mathematical calculations of the dimensions, weight, etc., of the Earth, Moon and Sun," which Mr. Ridsdale has asked me to read for him in his absence. This is only the first part of the paper. (*Paper.*)

At another meeting Mr. Ridsdale will give us the second part of his paper and will explain the application of the formulæ that he has given you this evening.

There was no discussion on this paper.

An approximate method of computing precession in certain cases.

By A. B. Chatwood, B.Sc., F.R.A.S., A.M.I.C.E.

The present paper suggests that when rectangular coordinates are used instead of right ascension and declination, the computation of precession can in many cases be much simplified. The method suggested can only be used within certain limits which depend on the declination, on the interval between the two epochs, on the area considered, and on the accuracy required.

If we assume that the rate of change of precession is, within the limited area, under consideration—taken in this paper as a square of $130' \times 130'$, corresponding to the plates of the astrographic catalogue—a linear function of the coordinates, we may then write as the annual precession in R.A. for any star.

$$Px + n\,(\alpha \cos A \tan D + \delta \sin A \sec^2 D).$$

Where Px is the precession of the plate centre

A.D the R.A and decl. of the plate centre

$\alpha\,\delta$ the angular distances in R.A, and decl. of any star from the plate centre expressed in circular measure.

Since $\alpha\,\delta$ can be expressed in rectangular coordinates of x y, with the plate centre as origin and A.D are constant

for any one plate, this at once leads to a correction for the precession.

$$Qx + Ry.$$

Where $Q = \frac{1}{300} T\, n\, \mu \cos A \tan D.$

$$R = \frac{1}{300} T\, n\, \mu \sin A \sec^2 D.$$

Where T is the number of years from one epoch to the other.

n the precession constant.

μ the circular measure of the unit in which x and y are measured ; in the present paper 5′ of arc or ·00145444 is used.

The factors cos A tan D ; sin A sec² D being computed for each plate centre.

We might write for the precession in R.A of any star using the same notation.

$$T[m + n \sin (A - \alpha) \tan (D + \delta)].$$

The method of computation above suggested is equivalent to neglecting the second and higher order terms in the expansion of this expression which is only permissible of T.D, α δ do not exceed certain values depending on the accuracy required. These limiting values might be determined by the evaluation of the remainder of the series after the terms of the first order ; but such evaluation cannot be carried out simply.

In Table I I give the computation of $[n \sin (A + \alpha) \tan (D + \delta)] - [n \sin A \tan D + Q x + R y]$ for the limiting values ± 65′ of α and δ.

It may be pointed out that the error thus computed which must be multiplied by the number of years between the epochs is the maximum error which can occur. The computation is in practice carried out as follows :—

If A′ and D′ be the coordinates of the plate centre at the epoch desired

A.D the corresponding coordinates at the epoch of the catalogue.

A and D are computed in the usual way from $m + n \sin A'$ tan D′ and n cos A′.

The values of x and y, the centre A.D being taken as origin, are taken from the catalogue and the factors Q.R applied. The resulting x′, y′ are then corrected for the projection in the usual manner.

Table II gives a number of examples and shows the errors [illegible] by the use of the method in working from an 1855

catalogue to the epoch 1900, the errors being given in units of 0″·03 of arc.

Similarly the precession in decl. is given by

$$S\,x$$

Where $S = -T\,n\,\mu \sin A$.

In Table II x″ has been computed by bringing up the stars to the epoch 1900 in the usual way and subsequently correcting to rectangular coordinates.

In the computation of x′ y′ Crelle's 3-figure multiplication tables have been used.

In conclusion I wish to express my thanks to my assistant, Mr. T. P. Bhaskara Sastri, B.A., who has assisted me in the preparation of the paper and has computed the tables.

Table I.

$$[\mu \sin (A+\alpha) \tan (D+\delta)] - [\mu \sin A \tan D + Qx + Ry]$$

Declination.

Right Ascension hours.	0°	15°	30°	45°	60°	75°
0	0·239	0·257	0·322	0·487	0·987	3 836
½	0·237	0·260	0·333	0·529	1·175	5·612
1	0·231	0·258	0·340	0·565	1·342	7·294
1½	0·220	0·251	0·342	0·589	1·487	8·854
2	0·206	0·241	0·337	0·604	1·605	10·250
2½	0·189	0·226	0·326	0·610	1·697	11·477
3	0·169	0·207	0·310	0·603	1·759	12·516
3½	0·145	0·186	0·288	0·603	1·792	13·345
4	0·118	0·160	0·261	0·559	1·801	13·935
4½	0·091	0·132	0·231	0·524	1·774	14·279
5	0·062	0·102	0·195	0·480	1·700	14·381
5½	0·030	0·069	0·157	0·426	1·619	14·243
6	0·001	0·035	0·117	0·367	1·503	13·870

Table II.

H. M. S.

Plate Centre. Epoch 1900 R.A. 0 0 0 Decl.—18°
Epoch 1855 ,, 23 57 41·65 ,, —18° 15′ 2″·4
Factors. Q—·00144 R + ·000039 S—·000035

Right Ascension. *Declination.*

x	x′	x″	Error.	y	y′	y″	Error.
			·0001				·0001
—12·7575	—12·7390	—12·7390	0	+ 2·4520	+ 2·4524	+ 2·4527	+3
— 4·9075	— 4·9001	— 4·9000	+1	+ 8·8520	+ 8·8522	+ 8·8520	—2
— 0·5325	— 0·5316	— 0·5315	+1	+ 8·8320	+ 8·8320	+ 8·8320	0
+10·2825	+10·2677	+10·2680	+3	+ 0·1320	+ 0·1316	+ 0·1320	+4
— 8·6925	— 8·6796	— 8·6790	+6	+ 9·4520	+ 9·4523	+ 9·4523	0
+ 4·4825	+ 4·4765	+ 4·4760	—5	+11·6520	+11·6518	+11·6520	+2

H. M. S.

Plate Centre. Epoch 1900 R.A. 3 4 0 Decl.—18°
,, 1855 ,, 3 1 55·82 ,, —18° 10′ 29″·8
Factors. Q—·00098 R—·00348 S+·00315

Right Ascension. *Declination.*

x	x′	x″	Error.	y	y′	y″	Error.
			·0001				·0001
—11·3160	—11·3030	—11·3025	+5	— 0·5593	— 0·5949	— 0·5947	+2
— 5·9310	— 5·9194	— 5·9195	—1	— 1·6593	— 1·6780	— 1·6778	+2
—10·7910	—10·8121	—10·8115	+6	+ 9·1207	+ 9·0867	+ 9·0870	+3
— 3·0160	— 3·0394	— 3·0390	+4	+ 7·5807	+ 7·5712	+ 7·5713	+1
+ 9·4840	+ 9·4709	+ 9·4705	—4	+ 1·1007	+ 1·1306	+ 1·1307	+1
+12·3240	+12·2875	+12·2870	—5	+ 7·0007	+ 7·0394	+ 7·0397	+3
—11·7710	—11·8008	—11·8000	+8	+11·9007	+11·8635	+11·8640	+5
+ 3·2590	+ 3·2210	+ 3·2205	—5	+10·0207	+10·0310	+10·0307	—3
+ 9·8490	+ 9·8010	+ 9·8005	—5	+11·0407	+11·0717	+11·0717	0

H. M. S.
Plate centre. Epoch 1900 R.A. 6 0 0 Decl.—18°
,, 1855 ,, 5 58 01·3 ,, —18° 00′ 03·9″
Factors Q 0000. R—·00484 S+·00437.

Right Ascension.				*Declination.*			
x	x′	x″	Error. ·0001	y	y′	y″	Error. .0001
—10·7250	—10·7654	—10·7650	+4	+ 8·3470	+ 8·3002	+ 8·3000	—2
— 9·6050	— 9·6131	— 9·6125	+6	+ 1·6670	+ 1·6250	+ 1·6250	0
— 7·9600	— 7·9637	— 7·9630	+7	+ 0·7670	+ 0·7322	+ 0·7323	+1
— 5·8800	— 5·9131	— 5·9125	+6	+ 6·8270	+ 6·8013	+ 6·8013	0
+ 0·0450	— 0·0126	— 0·0125	+1	+11·9270	+11·9272	+11·9270	—2
+ 1·3200	+ 1·3157	+ 1·3160	+3	+ 0·8870	+ 0·8928	+ 0·8927	—1
+ 5·3650	+ 5·3625	+ 5·3625	0	+ 0·5270	+ 0·5504	+ 0·5503	—1
+ 9·6350	+ 9·6052	+ 9·6055	+3	+ 6·1470	+ 6·1891	+ 6·1890	—1
— 2·9300	— 2·9881	— 2·9880	+1	+12·0070	+11·9942	+11·9940	—2
+ 3·1200	+ 3·0600	+ 3·0600	0	+12·4070	+12·4206	+12·4207	+1

H. M. S.
Plate centre. Epoch 1900 R.A. 9 4 0 Decl.—18°
,, 1855 ,, 9 1 55·32 ,, —17° 49′ 13·7″
Factots Q+·00102 R—·00336 S+·00304

Right Ascension.				*Declination.*			
x	x′	x″	Error. ·0001	y	y′	y″	Error. ·0001
—10·8060	—10·8543	—10·8550	—7	+11·0943	+11·0615	+11·0610	—5
—10·0610	—10·1143	—10·1150	—7	+12·7543	+12·7236	+12·7233	—3
— 6·3010	— 6·3430	— 6·3435	—5	+10·5943	+10·5751	+10·5750	—1
— 7·3560	— 7·4011	— 7·4015	—4	+11·1943	+11·1719	+11·1717	—2
— 2·9410	— 2·9563	— 2·9560	+3	+ 3·6543	+ 3·6453	+ 3·6453	0
+ 2·1690	+ 2·1587	+ 2·1590	+3	+ 3·6543	+ 3·6609	+ 3·6610	+1
+ 3·4190	+ 3·3969	+ 3·3970	+1	+ 7·6343	+ 7·6447	+ 7·6447	0
+ 3·7840	+ 3·7783	+ 3·7785	+2	+ 2·8543	+ 2·8658	+ 2·8660	+2
+ 5·1840	+ 5·1520	+ 5·1520	0	+11·1343	+11·1500	+11·1500	0
+ 7·2790	+ 7·2431	+ 7·2435	+4	+12·8743	+12·8964	+12·8963	—1

Plate Centre Epoch 1900 R. A. H. 12 M. 0 S. 0 Decl.—18°
,, 1855 ,, 11 57 41·84 Decl.—17° 44′ 57″6
Factors Q+·00142 R ·000 S ·000

Right Ascension. *Declination.*

x	x′	x″	Error.	y	y′	y″	Error.
			·0001				·0001
—11·6470	—11·6635	—11·6640	—5	+ 8·9680	...	+ 8·9673	—7
—10·3220	—10·3366	—10·3370	—4	+ 9·3480	...	+ 9·3477	—3
— 9·3770	— 9·3903	— 9·3905	—2	+ 5·7280	...	+ 5·7277	—3
— 7·2970	— 7·3074	— 7·3080	—6	+13·0280	...	+13·0277	—3
— 6·3470	— 6·3560	— 6·3565	—5	+ 7·9480	...	+ 7·9477	—3
— 4·7770	— 4·7838	— 4·7845	—7	+ 8·8880	...	+ 8·8880	0
— 0·5170	— 0·5177	— 0·5180	—3	+ 9·8280	...	+ 9·8280	0
+ 3·2630	+ 3·2676	+ 3·2675	—1	+ 4·0880	...	+ 4·0880	0
+ 5·6680	+ 5·6761	+ 5·6760	—1	+11·6680	...	+11·6680	0
+10·0080	+10·0222	+10·0220	—2	+ 6·2280	...	+ 6·2280	0

Plate Centre. Epoch 1900 R.A. H. 15 M. 4 S. 0 Decl.—18°
,, 1855 ,, 15 1 27·83 ,, —17° 49′ 29″·5
Factors Q+·00098 R+·00348 S—·00315

Right Ascension. *Declination.*

x	x′	x″	Error.	y	y′	y″	Error.
			·0001				·0001
—12·9215	—12·9241	—12·9245	—4	+ 2·8617	+ 2·9023	+ 2·9017	—6
—10·3115	—10·2815	—10·2815	0	+11·7817	+11·8141	+11·8137	—4
— 9·6565	— 9·6517	— 9·6520	—3	+ 4·1217	+ 4·1521	+ 4·1517	—4
— 3·1715	— 3·1301	— 3·1305	—4	+12·8417	+12·8517	+12·8513	—4
— 3·1465	— 3·1148	— 3·1150	—2	+10·0217	+10·0316	+10·0313	—3
+ 3·9385	+ 3·9508	+ 3·9505	—3	+ 2·4217	+ 2·4093	+ 2·4090	—3
+ 7·5235	+ 7·5614	+ 7·5615	+1	+ 8·7817	+ 8·7580	+ 8·7580	0
+9·6735	+ 9·7213	+ 9·7215	+2	+11·0417	+11·0112	+11·0110	—2

Plate Centre. Epoch 1900 R. A. H. 18 M. 0 S. 0 Decl.—18°
,, 1855 ,, 17 57 22·20 ,, —17° 59′ 54″·8
Factors Q=0. R=+·00484 S=—·00437

Right Ascension.				*Declination.*			
x	x′	x″	Error.	y	y′	y″	Error.
			·0001				·0001
—12·9400	—12·8953	—12·8950	+3	+ 9·2373	+ 9·2935	+ 9·2937	+ 2
— 8·6150	— 8·6108	— 8·6110	—2	+ 0·8773	+ 0·9149	+ 0·9150	+ 1
— 7·0400	— 7·0043	— 7·0040	+3	+ 7·3773	+ 7·4081	+ 7·4080	— 1
— 5·6150	— 5·5928	— 5·5930	—2	+ 4·5773	+ 4·6018	+ 4·6017	— 1
+ 2·4500	+ 2·5076	+ 2·5080	+4	+11·8973	+11·8866	+11·8863	— 3
+ 7·3050	+ 7·3602	+ 7·3605	+3	+11·4373	+11·4054	+11·4053	— 1
+ 8·7250	+ 8·7826	+ 8·7830	+4	+11·8773	+11·8392	+11·8390	— 2
+10·1500	+10·2071	+10·2075	+4	+11·8173	+11·7730	+11·7727	— 3
— 8·6700	— 8·6095	— 8·6095	0	+12·4773	+12·5152	+12·5150	— 2
— 3·3950	— 3·3345	— 3·3345	0	+12·3973	+12·4121	+12·4120	— 1
+ 7·8550	+ 7·9170	+ 7·9170	0	+12·7973	+12·7630	+12·7627	— 3

Plate Centre. Epoch 1900 R. A. H. 21 M. 4 S. 0 Decl.—18°
,, 1855 ,, 21 1 28·02 ,, —18° 10′ 45″·7
Factors Q=—·00102. R=+·00336 S=—·00304

Right Ascension.				*Declination.*			
x	x′	x″	Error.	y	y′	y″	Error.
			·0001				·0001
—12·7210	—12·7122	—12·7120	+ 2	— 1·2523	— 1·2137	— 1·2130	+7
— 7·4410	— 7·4376	— 7·4375	+ 1	— 1·2523	— 1·2297	— 1·2293	+4
— 5·5910	— 5·5911	— 5·5905	+ 6	— 1·7323	— 1·7153	— 1·7150	+3
+ 8·9390	+ 8·9635	+ 8·9625	—10	+ 9·6877	+ 9·6605	+ 9·6607	+2
+12·5890	+12·5751	+12·5750	— 1	— 0·3123	— 0·3506	— 0·3503	+3
+12·9090	+12·9133	+12·9130	— 3	+ 5·2077	+ 5·1685	+ 5·1687	+2
— 9·0160	— 8·9640	— 8·9630	+10	+12·7477	+12·7751	+12·7753	+2
— 2·1460	— 2·1024	— 2·1015	+ 9	+12·3477	+12·3542	+12·3543	+1
+ 2·1690	+ 2·2017	+ 2·2020	+ 3	+10·4077	+10·4011	+10·4010	—1
+ 9·2440	+ 9·2680	+ 9·2680	0	+ 9·9277	+ 9·8996	+ 9·8997	+1

Saturn in a small telescope.

By C. V. Raman, M.A.

At one of our recent meetings I mentioned that Cassini's division is now a fairly easy object even in a $2\frac{7}{8}''$ telescope. This statement has been received with considerable reserve by some of our members, and I have heard doubts expressed whether such a performance was even theoretically possible with the aperture. The following calculations may therefore be of interest. In a paper published in Vol. II of the Journal I discussed the phenomena of the diffraction of light. I need not go over the same ground, and will now deal only with the application of the principles explained in that paper.

If the object-glass of a telescope is covered by a rectangular aperture, and a point-source of light such as a star is viewed through it, the principal part of the image seen in the field consists of a small rectangular area of light, the angular distance of the dark margin from the centre in seconds of arc being given by the formula.

$$\frac{\text{Wave length of light}}{\text{Width of aperture}} \times \frac{180 \times 3600''}{\pi}$$

Taking the wave-length as $\frac{1}{50,000}$ of an inch and the aperture as $2\frac{7}{8}''$, the angle is found to be 1·4 seconds of arc. If a double star whose angular separation is 1·4 seconds is seen through the instrument, there would be a distinct falling off in illumination between the positions of the geometrical images which might enable the object to be distinguished from a single star under favourable conditions. This falling off in illumination would be more easily appreciated if instead of two point sources of light, we have two fine linear sources close together and parallel to the edges of the aperture. Experiment shows that resolution is quite possible at an angular separation of the two sources equal to that given by the above formula ; the illumination in the centre of the field being about $\frac{1}{8}$th less than on either side of it, if the two line-sources are of equal intensity. If the angular separation is double this, *i.e.*, 2·8″, the field would show an absolutely black line separating the two components.

If now we pass from the case of two parallel linear sources to that of two illuminated *surfaces* separated by a dark line of division, the conditions for resolution are far more favourable. This can be readily understood. It is obvious that the dark division would be more readily obliterated by

diffraction if the whole light of the source were concentrated immediately on either side of it, instead of being spread away to some distance each way. If the source consisted of two equally illuminated surfaces separated by a dark gap of 1·4″, the telescopic field of a 2⅞″ glass would still show the division very dark. With a dark gap of 0·5″ the illumination in the centre of the field would still be 50 per cent. less than on either side of it and this should be capable of being observed with ease.

Let us now apply these deductions from mathematical theory to the actual case of Saturn's rings. For the 16th February 1914, we have from the Nautical Almanac figures and the accepted radii of the rings, the following radial dimensions :—

	Major axis.	*Minor axis.*
A Ring ...	... 5·7″	2·5″
Cassini's Division	... 1·0″	0·5″
B Ring ...	... 9·3″	4·1″

From these figures and what was said above it is evident that a 2⅞″ telescope should be capable of showing Cassini's division right round the ring at the present epoch. A steady instrument and a comfortable position for the head and eyes of the observer should be sufficient to enable any of our members to verify this by an evening observation in the quiet of their homes. By stopping down the telescope I can get glimpses of Cassini's division even with 2″ aperture and the difference in the brightness of the A and the B rings is very evident with such small apertures.

Some mathematical calculations of the dimensions, weight, etc., of Earth, Moon and Sun.

By Revd. A. C. Ridsdale, M.A.

The subject of my paper is "some mathematical calculations of the dimensions, weight, etc., of Earth, Moon and Sun." I say "mathematical calculations," because I confine myself entirely to the mathematical part of the work, and make no attempt to treat of the observations and experiments, upon

which many of these calculations are based. The formulæ, which I propose to put before you, are of course arrived at through the ordinary methods of the various branches of mathematics, but as it would be entirely outside the purpose of a short paper to discuss the mathematical processes by which these formulæ are found, except in special cases, I only propose to give you them for the most part just as they stand, exhibiting the working thereon. I feel that, although many have doubtless worked out many of these calculations for yourselves, and some have made a study of the mathematics underlying them, yet it may perhaps not be unprofitable for all of us, to go through, step by step, in as clear and orderly a manner as possible, some of the simplest calculations, which every one who has any pretensions to being a serious student of astronomy, should be thoroughly conversant with, and have absolutely, as it were at his finger's end. One cannot insist too strongly on the fact, that no headway can be made in the noble science of astronomy, if one is continually shirking all the calculations, with which it is so inextricably bound up. In this connection, allow me to quote the words of one of the greatest of astronomical observers Sir John Herschell. He says—"Admission into the sacred temple of astronomy, can only be gained by one means, namely, sound and sufficient knowledge of mathematics, the great instrument of all exact inquiry, without which no man can ever make such advances, in this or any other of the higher departments of science, as can entitle him to form an independent opinion on any one subject of discussion within their range." In these mathematical calculations which follow, I shall confine myself to the very simplest processes, which no one will have, I hope, any difficulty in understanding and remembering; concerning the dimensions, surface area, volume, form, ellipticity, mass, density, specific gravity, surface gravity, and tidal diminution of gravity, of the Earth, Moon, and Sun. I propose, with the approval of the President, to put before you at this meeting, only the very first part of my calculations regarding the Earth, namely, the Earth's dimensions.

First of all, to start at the very beginning, let us take the *radius of the Earth*—

$$r = \frac{\text{length of arc}}{\text{No. of degrees in arc}} \times \text{radian.}$$

thus F 1^0 (average) arc = 365,000 feet = (about) $69\frac{1}{4}$ miles.

and radian = $57{\cdot}29^0$ = (about) $57\frac{1}{4}^0$

then $r = (69\frac{1}{4} \times 57\frac{1}{4})$ miles = 3,960 miles.

and diameter $= 2r = 7{,}920$ miles.

and circumference $= 2\pi r = (2 \times 3{\cdot}1416 \times 3{\cdot}960)$ miles.

$= 24{,}900$ miles.

or $r =$ any arc $\times \dfrac{\text{seconds in radian.}}{\text{seconds in } \angle \text{ subtending arc}}$

and F $a = 1^0$ arc.

and $1^0 = 365{,}000$ feet.

and radian $= 206{,}265$ seconds.

then $r = 365{,}000 \times \dfrac{206{,}265}{3{,}600}$ feet.

$= 20{,}912{,}979$ feet.

I may remind you that of *the three quantities*—

(1) the angular value of an arc, (2) its linear value, (3) the length of the radius; if any two of these quantities be given, the third can be mathematically calculated.

To what extent do the mountains and oceans *modify the exact globularity* of the Earth?

if 20 ft. represent Earth's diameter, $=8000$ m.

then $\frac{20}{8000}$ ft. $=\cdot03$ inch $=1$ mile

and highest mountains are 5 miles high.

$\therefore$ $\cdot03 \times 5$ inch $= \frac{3}{20}$ inch $=$ height of the highest mountains—a very small amount, relative to a globe of 20 ft. diameter.

To find any *longitudinal arc in any other latitude* than zero. The trigonometrical formula is, non-equatorial arc, = (equatorial arc $\times$ cos latitude).

For example, let us find the value of 1^0 arc at latitude 45^0.

If 1^0 arc at equator $= 69\frac{1}{4}$ miles

then 1^0 arc at 45^0 lat. $= (69\frac{1}{4} \times \cos 45^0)$ miles

$= (69\frac{1}{4} \times \cdot70711)$ miles

$=$ (about) 48 miles.

We will next take the *Earth's surface area*. There are several mathematical formulæ, which give us this quantity.

For example, $4 \times$ area of great circle

$= 4\pi r^2 = 4 \times 3{\cdot}1416 \times (3960)^2$ square miles

$=$ (less ellipticity of $\frac{1}{298}$th) 197,000,000 square miles

or $= \pi \times (\text{diameter})^2 = 3\frac{1}{7} \times (7920)^2 =$ &c.

or $=$ diameter $\times$ circumference $= 7920 \times 24{,}900 =$ &c.

or $= \dfrac{(\text{circumference})^2}{\pi} = \dfrac{(24{,}900)^2}{3{\cdot}1416} =$ &c.

Earth's volume—The volume of a sphere is

$= \frac{1}{6}\pi \times (\text{diameter})^3 = \cdot 5236 \times (7920)^3$

$= 259{,}800{,}000{,}000$ cubic miles

$= 38{,}242{,}027{,}930$ billion cubic feet

or $= \frac{4}{3}\pi \times (\text{radius})^3$

$= \frac{4}{3} \times 3\frac{1}{7} \times (3960)^3 =$ &c.

or (by the method of solid rectangular conical sectors)

$= \frac{1}{3} r \times$ area of surface $= (\frac{1}{3} \times 3960 \times 197{,}000{,}000)$ cubic miles $=$ &c.

(To be continued.)

Extracts from Publications.

Jupiter visible before Sunrise.—The planet Jupiter can now be well seen in the mornings, and it is important that telescopic observers examine his disc carefully and note the chief features. Last year the equatorial current had increased its rate of movement, its rotation being 9h. 50m. 11s. from a number of spots on the south edge of the northern equatorial belt. Are these markings still visible, and what is their velocity as compared with that determined during the previous opposition ?

The great red spot also exhibit a quickening of speed in 1914, the rotation period being 9h. 55m. 35s. It is probable that at the present time the red spot precedes the zero meridian of System II (see Ephemeris for physical observations of Jupiter in Nautical Almanac) about 3h. 40m. It is impossible to tell exactly, however, because the planet has been too near the Sun during the past winter for corrective observations to be made. Transits of the red spot and hollow in the southern belt may, however, be looked for at the following times :—

		H.	M.			H.	M.
April	14	14	27	May	3	15	6
,,	16	16	5	,,	8	14	14
,,	21	15	12	,,	15	14	59
,,	26	14	20				
,,	28	15	58				

Some estimated transits would be valuable in order to determine what the rate of rotation has been during the last six months.

The great south temperate spot now precedes the red spot. The former was no less than about 135° in length during last opposition, and it may ultimately extend all round Jupiter and darken the previously brilliant south tropical zone.

[*Nature.*]

A Faint Companion to Capella.—An interesting discovery has been made by Dr. R. Furuhjelm (Astronomische Nachrichten, No. 4715), who has found that Capella, a spectroscopic double star, is accompanied by a faint companion (phot. mag. 10·6) at a very great distance. The absolute positions of the stars, according to the Helsingfors' catalogue plates are as follows :—

	a 1900·0			1900·0 epoch			
	h.	m.	s.				
Capella ...	5	9	18·09	... +	45°	53′ 49″·11	895·42
The faint star	5	10	1·26	... +	45°	44′ 23″·9	

The companion is distant from Capella by 12 3 3, and the position angle is 141·20°. The discovery was made by comparing the proper motions of the stars in the neighbourhood of Capella determined from photographs of the region taken at two different epochs at Helsingfors. Dr. Furuhjelm's proper motion for the faint star gave the values 0·422 in the direction 170·9°, while the values for Capella as determined by Boss were ·0438 in the direction 168·7°. Other stars in the vicinity have no such physical relationship.

The Solar System.—The following neat empirical formula connecting certain elements of the known planetary satellites is given by M. F. Ollive in a modest little note communicated to the French Academy of Sciences (Comptes Rendus, Vol. CLVII, No. 26, p. 1501). Let R represent the mean distance of the satellite from the planet around which it gravitates, V its orbital velocity, R the mean distance of the planet from the Sun, and r its mean radius, then, M. Ollive states $r^3 = KRR V^2$. In c. g. s. units the constant $k = 4{\cdot}313 \times 10{\cdot}8$.

The data for the twenty-six known satellites in the solar system necessary for calculating the planetary radii are tabulated, together with the deduced ratio of the radius of the planet to that of the Earth compared with the measured values. The formula gives the radius of the Earth with great accuracy, the ratio deduced measured being 1·0001, according to our calculation ; for Mars also the deduced radii are almost identical *inter se*, and with the measured value. For Jupiter and Saturn, whilst the deduced values are highly

consistent among themselves, except that given by Saturn's ninth and most distant satellite, they are slightly in excess (approx. 6 per cent. and 2 per cent. respectively) of the measured radii. For Uranus and Neptune the formula gives results roughly 50 per cent. and 100 per cent. too high respectively. [*Nature.*]

The Smithsonian Astrophysical Observatory.

The report of the Astrophysical Observatory for 1913, under the direction of the Smithsonian Institution, contains a good account of progress made: in fact, the Director, Mr. Abbot, refers to the work of the observatory as "uncommonly successful." We notice that for the solar work at Mount Wilson there has just been erected a Tower telescope, 40 ft. high, for use with the spectrobolometer, for the study of the distribution of radiation over the Sun's disc. The report states many results of the year's work. Thus the mean value of the solar constant of radiation at the Earth's mean distance from the Sun, from about 700 observations made at high and low stations between 1902 and 1912 is 1·932 calories per square centimetre per minute. The fluctuation of the 'Solar constant' values is attributed to the variability of the Sun, and in addition to the periodicity due to the sun-spots, there is another irregular, non-periodic variation, sometimes running its course in a week or ten days, at other times in longer periods and varying over irregular fluctuations of from 2 to 10 per cent. of the total radiation in magnitude. Further, a combination of the effects of sun-spots and volcanic haze is put forward as explaining the principal outstanding irregularities in the temperature of the Earth for the last thirty years. Finally, in the Californian expedition, in which sounding baloons were employed, the solar radiation values at very high altitudes indicate that the direct pyrohelion metric observations gave results of the same order of magnitude as the solar constant work of 1902—1912 by high and low Sun observations on homogeneous rays, according to Langley's methods.

The New Solar Cycle.—The long period of apparent rest which the solar atmosphere has been recently undergoing has now been broken by the comparatively large sun-spot which developed during the course of last week. The sun-spot activity of the last few years has been well summarised in the annual report of the Council of the Royal Astronomical Society (Monthly Notices, February 1914). In this we are told that the past year has been a year of minimum activity

of sun-spots, more than a century having elapsed since the Sun exhibited such complete and prolonged quiescence. The following brief table is gathered from the report above mentioned, and brings out clearly the exceptional nature of the year 1913 :—

Year.	Days without spots.	Mean daily spotted area in millionths.	No. of separate groups.
1911 ...	... 183	64	62
1912 ...	... 246	37	39
1913 ...	... 320	5	15

It is stated that no year since 1810 has given such a barren record as that just elapsed. The new cycle was indicated last year by two groups in high latitude, the chief criterion for the beginining of a new cycle.

Relation between Stellar Spectra, Colours and Parallaxes.— In Astronomische Nachrichten, No. 4722, Herr P. Nashan describes the results he has obtained in comparing the colours, spectra and parallaxes of a number of stars. Dealing first with 101 stars, he divides them first into three classes: a, β and τ, according as the stars are white, yellow, or re : the parallaxes are also grouped with three divisions as follows :— 0·000″ to 0·050″, 0·050″ to 0·100″, and 0·100″ to 0·200″. The comparison shows that the white stars decrease with increasing parallaxes : on the other hand, the red stars increase with increasing parallaxes. The fact that there is a close relationship between the colour and the spectrum of a star has led him to compare the sepectra of 246 stars with their parallaxes. The results are best shown as follows :—

Spectrum.	No. of stars.	Parallax.							
		0″·000—0″·050		0″·050—0″·100		0″·100—0″·150		0″·150 +	
		n	%	*n*	%	*n*	%	*n*	%
B	11	7	63·6	3	27·3	1	9·1	0	0
A	28	8	28·5	8	28·5	7	25·0	5	18·9
F	59	19	32·2	22	37·3	15	25·5	3	5·1
G	64	13	20·3	22	34·4	27	42·2	2	3·1
K	70	13	18·6	21	30·0	23	32·9	13	18·5
M	14	3	21·4	2	14·3	5	35·7	4	28·6

Herr Nashan then couples up the B and A stars into a white group, and F and G into a yellow group, and the K and M stars into a red group, and concludes that the relative number of white stars decreases with increasing parallaxes, while the relative number of the red stars increases with increasing parallaxes, a result similar to that obtained with colour alone. The communication concludes with the list of the 246 stars employed, giving their positions for 1900·0, a parallax, type of spectrum and colour.

[*Nature.*]

Memoranda for Observers.

[Standard Time of India is adopted in these Memoranda.]

For the month of June 1914.

Sidereal time at 8 p.m.

		H.	M.	S.
June	*1st*	12	36	54
,,	*8th*	12	4	30
,,	*15th*	13	32	6
,,	*22nd*	13	59	42
,,	*29th*	14	27	18

From this table the constellations visible during the evenings in June can be ascertained by a reference to a star chart, as the above hours of sidereal time represent the hours of Right Ascension on the meridian.

Phases of the Moon.

			H.	M.	
June	*1st*	First Quarter	... 7	33	P.M.
,,	*8th*	Full Moon	... 10	48	A.M.
,,	*15th*	Last Quarter	... 7	50	P.M.
,,	*23rd*	New Moon	... 9	3	,,
,,	*30th*	First Quarter	... 12	54	,,

Meteors.

	Radiant. R. A.	Dec.	Character.
May-June	... 353°	+39°	Swift ; streaks.
May-June-July	... 252°	−21°	Slow ; trains.
June-July-Aug.	... 302°	+23°	Swift.
June 4th—13th	... 312°	+61°	Swift ; streaks.
,, *20th*	... 335°	+57°	Swift.

The Planets.

Mercury—Is an evening star throughout the month, and will be at greatest elongation, 24° 55′ East, on the 19th and will therefore be visible for about fourteen days before and after that date.

Venus—Is also an evening star throughout the month, setting two hours after the Sun on the 1st and about two and a half hours after on the 30th.

Mars—Is also an evening star and has moved into Leo where he sets about four and a half hours after the Sun. Position on the 15th R.A. 9·46, Dec. 14° 47′ North.

Jupiter—A morning star, continues in Capricornus, rising seven hours before the Sun on the 1st and nine hours before on the 30th. He will therefore be visible above the south-eastern horizon about the middle of the month at midnight. Position on the 15th R.A. 21·39, Dec. 14° 51′ South.

Saturn—Is an evening star until the 13th and is then in conjunction with the Sun, and becomes a morning star until December 21st. Position on the 15th R.A. 5·25, Dec. 20° 55′ North.

Uranus—Is in Capricornus. Position on the 15th R. A. 20·55, Dec. 18° 1′ South.

Neptune—Is in Cancer. Position on the 15th R.A. 7·54, Dec. 20° 26′ North.

Notices of the Society.

Election of Members.

THE attention of members is invited to Bye-Law No. 14, regulating the election of persons who desire to join the Society. It is hoped that those who are already members will induce others to join. Forms of application can be had from the Secretary.

Change of Addresses.

It is particularly requested that when members change their addresses, they will kindly notify the new address to the Secretary. The omission to do this is likely to cause the loss of the JOURNALS and other communications.

Telegraphic Address.

The address of the Society has been registered at the Telegraph Office, Calcutta. Telegrams should be addressed "Astronomy," Calcutta.

The Library.

A subscription list exists and several members in Calcutta have subscribed and enabled the Council to make a beginning with the Library. Other members outside Calcutta, however, have not, except in one or two cases, yet come forward, and as the Library will be one of the most important adjuncts of the Society, and will be available to members both in and out of Calcutta, those who have not yet done so are invited to help the Society in making progress with this important branch of the work. Suggestions as to useful books for the Library will also be welcomed by the Librarian.

A number of books have already been received and can be borrowed by members in accordance with the Bye-Laws.

The books available can be ascertained from the Assistant Librarian. The reading-room of the Society in the Imperial Secretariat is now opened for the use of members daily from 5 to 7 P.M., except on Wednesdays and holidays, and from 3 to 5 P.M. on Saturdays unless that day is a holiday.

The Journal.

The following charges have been fixed for back numbers of the JOURNAL :—

For members.—Per copy 12 annas ; per volume Rs. 5.

The Star Chart.—As. 12 a copy.

For non-members.—Rs. 1-8 per copy.

The Star Chart.—Rs. 2 a copy.

Subscriptions.

Subscriptions for the current session fell due on 1st October 1913. Those who have not paid in their subscriptions are requested to remit them to the Treasurer without delay.

Papers for Meetings.

It is requested that drawings which accompany papers for reproduction in the JOURNAL may be made with Indian ink on white paper. This will insure a clear reproduction.

List of Instruments.

With a view to enable the Council to obtain a knowledge of the instrumental equipment of the members, it is requested that those members who possess any instrument suitable for astronomical work will kindly send details to the Director of Instruments of its kind, size and power.

Addresses of Officers.

Owing to inconvenience which has arisen from addressing the officers of the Society at their private address, it has been decided to receive communications on the business of the Society in future as follows :—

	To
Money Orders or letters containing money or cheques.	RAI BAHADUR U. L. BANERJEE, Office of the Accountant-General, Bengal, 3, Koila Ghat Street, Calcutta.
All other communications ...	(*Name*) D. N. DUTT, ESQ. (*Designation*) Business Secretary of the Astronomical Society of India, Imperial Secretariat (Treasury) Buildings, Calcutta.

It is requested that communications may be addressed accordingly.

Officers and Council.

FOR THE SEASON 1913-14.

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MRS. PERCY BROWN.

The Journal of the Astronomical Society of India.

VOL. IV.] SESSION 1913-1914. [NOS. 7 TO 9.

Report of the Meeting.

THREE Ordinary Monthly Meetings of the Society were held on the 28th April, 26th May and 30th June 1914, at 5-30 P.M., in the Imperial Secretariat (Treasury Buildings). The papers read at these meetings are published in this issue.

The presents received since the date of the meeting held on 31st March 1914 and numbering 47 were announced, and the thanks of the members were accorded to the donors.

The election by the Council of Mr. R. J. Pocock, B.A., B.Sc., Director, Nizamat Observatory, Hyderabad, of Mr. H. S. Dhable, I.C.S., Offg. District and Sessions Judge, Cuttack, and of Mr. R. D. Sinha, Moradabad, Lucknow, as members of the Society, was confirmed.

Some mathematical calculations of the dimensions, weight, etc., of Earth, Moon and Sun.

BY REVD. A. C. RIDSDALE, M.A., F.R.A.S.,

(*continued.*)

Earth's form.—

A true globe would not be compatible with rotation. Thus measurements show that degrees of arc of the Earth's circumference along a meridian arc of variable length. In order to find the Earth's ellipticity mathematically, we must first measure the lengths of arcs along a meridian from Equator to pole. Thence we can find their radii of curvature, which are the radii of their osculatory circles, and hence from the evolute of their centres, we can assign by the principles of conic sections, the proportions as well as the actual lengths of all these radii, and hence the Earth's true form.

Thus if XY be any arc, and G be a point on the Evolute where the normals of X and Y meet, and if l' and l represent the latitudes of X and Y respectively.

Then the circular measure of $XGY = \frac{arc\ XY}{YG}$

$$\therefore\ YG = \frac{arc\ XY}{\text{circ. meas. of } XGY} = \frac{\text{arc } XY}{(l'-l) \times \frac{\pi}{180}} = \frac{\text{arc } XY}{(l'-l)} \times \frac{182}{\pi}$$

The Earth's ellipticity $= \frac{1}{298}$

The lengths of degrees of latitude vary between
68·8 miles = 363,000 ft. at the Equator
and 69·4 miles = 368,000 ft. at the Poles.

An ellipse is shorter than its circumambient sphere, by half its ellipticity.

Therefore, a meridian is shorter than the Equator by $\frac{1}{2} \times \frac{1}{298} = \frac{1}{596}$ th

$\therefore$ a meridian $= 24{,}900 \times \frac{595}{596}$ miles in length

$= 24{,}856\frac{1}{2}$ miles in length.

Earth's Ellipticity.—

Let E = equatorial radius, and let P = Polar radius

then ellipticity $= \frac{E-P}{E} = \frac{3963-3949{\cdot}7}{3963}$

$$= \frac{13\frac{1}{2}}{3963} = \frac{1}{298} \text{ th.}$$

Earth's Eccentricity $= \sqrt{\frac{E^2-P^2}{E^2}} = \sqrt{\frac{E^2-P^2}{E^2}}$

$$= \frac{(3963)^2-(3949{\cdot}7)^2}{3963}$$

$$= {\cdot}0826$$

The Earth's form is the figure produced by the revolution of the Ellipse about its minor axis, which is an oblate spheroid.

The other chief methods of ascertaining the form of the Earth which we can only barely mention here, are the dynamical methods of (1) calculating the value of the irregularities in the Moon's motion that are due to the Earth's elliptical form, (about 8″), which works out at something between $\frac{1}{295}$ and $\frac{1}{311}$; (2) calculations from the variation of gravity at different points on a meridian; and (3) calculating the effects of luni—solar nutation, from which Harkness makes the Earth's ellipticity to be $\frac{1}{297}$ th. But this method is not very certain, as the distribution of the Earth's matter is not accurately known.

Earth's mass.—The best method for calculating the Earth's mass is by that of the "Torsion balance." As I warned you, however, I cannot enter into the details as to how the practical experiment is carried out. Any elementary text-book of astronomy will explain that. The mathematical principle of the calculation is simply that we compare the amount which a large ball, of known mass and radius, is able to attract a small body, as compared with the amount the Earth is able to attract it, or in other words its weight. It is a purely dynamical calculation. The ratio will be proportional to their respective masses, and inversely proportional to the square of their radii.

Thus if x = Earth's mass required, and a = amount of attraction of large ball, and w = that of the Earth, and r =

radius of large ball, and R = radius of Earth, and m = mass of large ball the formula will be—

$$x = m \times \frac{W}{a} \times \frac{R^2}{r^2}$$

The Earth's mass can also be calculated by means of the common balance.

If, for example, a small body when attracted by a large one placed above it loses ·00000001 of its weight, and the large body is a globe of 1 foot radius, and weighs 3 cwt.

Let x = weight of Earth (required) in tons

then $\cdot 00000001 : 1 :: \frac{\cdot 15}{7} : \frac{x}{(20{,}900{,}000)^2}$ tons

$$\therefore x = \frac{(20{,}900{,}000)^2 \times \cdot 15}{\cdot 00000001} \text{ tons}$$

$$= \frac{43{,}681 \times 3 \times 10^{18}}{20} \text{ tons}$$

$= 6552 \times 10^{18}$ tons, or 6552 trillions of tons
(a more accurate basis of calculations gives 5840 trillions).

The result is indeed a little too large a quantity, because we had supposed too large a loss of weight in the experiment. The mass of the Earth can also be calculated by the dynamical methods of—

(1) the position of the centre of gravity of Earth and Moon, being = ½ the Sun's angular displacement at first and last quarters; their combined mass being known from the orbital motion round the Sun.

(2) by calculating the attraction of the superposed masses of water which we call the tides.

The old mountain or "Schehallien method" (as also the mine experiment) is too inaccurate to yield results of any value. The mathematical principle involved, is the measurement of the difference between the geographical and astronomical latitudes of two places, due to the attraction of the known mass of a mountain between them. I need hardly remind you that Mass is not strictly equivalent to weight. Whilst Mass is a constant quantity, weight is a variable one, because weight unlike mass is proportional to the variations of gravity, which is itself proportional to the square of the distance from the centre.

The Density of the Earth—

$$= \frac{\text{mass}}{\text{volume}} = \frac{6 \times 10^{21}}{259{,}850{,}000} \text{ tons in 1 cubic mile.}$$

$$= \frac{8{,}960 \times 6{,}000{,}000{,}000{,}000{,}000{,}000}{259{,}850{,}000 \times (1760 \times 3)^3} \text{ lbs. in 1 cubic foot.}$$

= 342 lbs. in 1 cubic foot.

Specific gravity of Earth—

= number of lbs. in 1 cubic foot of Earth's matter divided by the number of lbs. in 1 cubic foot of water.

$$= \frac{342}{62\frac{1}{2}} \text{ (since 1 cubic foot of water weighs } 62\tfrac{1}{2} \text{ lbs.)}$$

= 5·472 (where water is unity).

I may add that, whilst 5·5 is the density of the Earth as a whole, or in other words its average density, only 2·6 is the density of the Earth's surface. Laplace calculates that 10·74 is the density of that portion of our globe which lies within a sphere of 3,000 miles radius, and that is more than four times the surface density. The pressure towards the centre of the Earth can thus be calculated as rather over three million tons per square foot.

The surface gravity of Earth—

$$= \frac{\text{Earth's mass}}{(\text{Earth's radius})^2}$$

Weight of bodies on the Earth's surface

$$= \frac{\text{Earth's mass} \times \text{body's mass}}{(\text{Earth's radius})^2}$$

Owing to the so-called centrifugal force (which would I think be more accurately styled "resistance to deviation") surface gravity on the Earth is not a constant quantity. The loss of gravity at the Equator, is the fraction represented by the number of feet in the Earth's radius, multiplied by the square of the radius per mean Solar second (in feet), and divided by the number of feet per second represented by gravity.

Thus $C = \frac{V^2}{R} = \frac{4\pi^2 R^2}{t^2} \times \frac{1}{R} = \frac{4\pi^2 R}{t^2}$ hence loss of gravity $= (3960 \times 5280) \times \frac{4\pi^2}{(86400)^2} \times \frac{1}{32\frac{1}{6}}$

$$= \frac{\cdot 11127}{32\frac{1}{6}} = \frac{1}{289.}$$

and since $C = \frac{V^2}{R}$; if velocity be ×17 at the Earth's equator,

then $C = (17)^2 \times$ present centrifugal force $= 289 \times$ present centrifugal force, thus $C = 289 \times \frac{1}{289} g = 1g$. In this case bodies at the Equator would weigh zero.

The weight then of a body is less at the Equator than at the poles (owing to centrifugal force) by $\frac{1}{289}$th. At other latitudes than at the Equator the centrifugal force $C^1 = C \cos^2 \phi$, ϕ representing the angle of latitude. The tangential component is given by the formula $C^1 = C \cos \phi \sin \phi$.

There is another reason, however, why the surface gravity at the Equator should be less than at the Poles, *viz.*, because the radius is greater at the Equator than at the poles. And gravity is reduced in the ratio of the square of the radius. This works out to a loss of $2\frac{5}{8}$ oz. on 100 lbs., represented by the fraction $\left\{ 1 - \frac{(\text{Polar } r)^2}{(\text{equatorial } r)^2} \right\}$ 100 lbs.

That is, a body weighing 100 lbs. $2\frac{5}{8}$ oz. at the poles will weigh 100 lbs. at the Equator. In order to find the total diminution of gravity at the Equator, the amount due to centrifugal force and that due to increased radius have of course to be added together, thus :—

$$\left(\frac{1}{289} + \frac{1}{595{\cdot}5} \right) g = (\text{about}) \frac{1}{194} g.$$

Variations of the gravitational force can also be dynamically calculated in terms of a second's pendulum.

Since $t = \pi \sqrt{\frac{l}{g}}$, and $t^2 = \frac{\pi^2 l}{g}$

therefore $g = \pi^2 \times$ length of pendulum (in feet) $\div t^2$ (= unity). In the latitude of Greenwich, such a pendulum is $3\frac{1}{4}$ feet in length.

Gravity at Greenwich $= (\pi^2 \times 3{\cdot}25)$ feet
$= (9{\cdot}86 \times 3{\cdot}25)$ feet
$= 32{\cdot}045$ feet.

"per second per second," which means, of course, the velocity with which a body would continue to fall in perpetuum, if gravity ceased to operate upon it after the first second. If we take the two causes together, a body weighing 194 lbs. at the Pole will weigh 193 lbs. at the Equator, or an ordinary clock pendulum would lose about 2·25 minutes in a day if transferred from London to Singapore.

Loss of gravity due to tide-raising forces.—

Lastly, it may be of interest to point out the loss of weight incurred by a body on the surface of the Earth, when directly under the Moon, or on the opposite side of the Earth from the Moon. On geometrical principles (which are too elaborate to state here) it can be shown that directly under the Moon, the tide-raising force upon the body is $\frac{1}{3^{\frac{1}{0}}}$ × Moon's whole attraction. And as the Moon's mass is $\frac{1}{3^{\frac{1}{0}}}$ × Earth's mass, and her distance is 60 × Earth's radius, the amount of diminution of gravity, under the Moon can be expressed by the following formula, if d denotes the ratio of the Moon's distance to the Earth's radius, thus—

$$g \times \frac{\text{Moon's mass}}{\text{Earth's mass}} \times \frac{1}{3^{\frac{1}{0}}} \times \frac{1}{d^3}$$

$$= g \times \frac{1}{81} \times \frac{1}{30} \times \frac{1}{3600}$$

$$= \frac{1}{8,748,000} \text{ of gravity.}$$

Thus the Moon's tide-raising force on a body is less than one eight-millionth of the Earth's surface gravity. Similarly the Sun's tide-raising force also reduces the Earth's gravity, when directly overhead or underfoot. And since the tide-raising force varies inversely as the cube of the distance (and not as its square) the tide-raising force of the Sun works out at about $\frac{2}{5}$ of that of the Moon.

Hence the weight of a body when directly under th Sun is diminished by $\frac{1}{8,748,000} \times \frac{2}{5}$th

$$= \frac{1}{21,870,000} \text{ th.}$$

In other words a body which normally weighs 1,000 tons, loses 1·714275 oz., when the Sun is overhead, or underfoot that is at mid-day or mid-night.

But the tide-raising forces of both Sun and Moon, when overhead, are slightly greater than when underfoot, because, when overhead, the ratio between the Earth's radius and their distances is slightly greater (especially in the case of the Moon) than when underfoot.

Thus the Moon's tide-raising force on a body nearest to her is $g \times \frac{\cdot 0123}{(59)^3}$

but on a body farthest from her on the Earth's surface is

$$g \times \frac{\cdot 0123}{(61)^2}$$

the difference being $\cdot 00000023 \times g$.

Finally, let me conclude my paper by venturing to remind you of the following mathematical relations and differenecs; which are of the greatest importance in astronomy :—

That every atom in the Universe attracts every other atom. But that (for convenience sake) it is possible to regard a homogeneous sphere as attracting from its centre of mass.

That the attraction at the Earth's surface $= \frac{\text{Earth's mass}}{(\text{radius})^2}$

But that the weight of bodies at the Earth's surface = the above quantity × body's mass.

That the accelerating force on

$$M_{\bar{2}} = \frac{M_{\bar{1}} \times M_{\bar{2}}}{(\text{distance } M_{\bar{1}} M_{\bar{2}})^2} \div M_{\bar{2}} = \frac{M^1}{d^2}$$

and that the accelerating force on—

$$M^1 = \frac{M_{\bar{1}} \times M_{\bar{2}}}{(\text{distance } M_{\bar{1}} M_{\bar{2}})^2} \div M_{\bar{1}} = \frac{M_{\bar{2}}}{d^2}$$

That the gravitational force between two bodies

$$= \frac{M_{\bar{1}} \times M_{\bar{2}}}{d^2}$$

But that the relative acceleration between two bodies

$$= \frac{M_{\bar{1}} + M_{\bar{2}}}{d^2}.$$

That accelerating force is a one-dimensional quantity, thus;

$$\frac{\text{mass (3 dimensional)}}{\text{distance}^2 \text{ (2 dimensional)}}$$

But that weight is a four-dimensional quantity, thus; mass (3 dimensional) × gravitational force (1 dimensional).

That gravitational force on $M_{\bar{2}} = \frac{M_{\bar{1}}}{(r)^2}$

But that tidal force on $M_{\bar{2}} = \frac{M_{\bar{1}}}{(r)^3}$

A Paper on Jupiter.

By Revd. J. Mitchell, M.A., F.R.A.S.

In my lecture on Jupiter in the Town Hall on the 12th February 1914, I referred in some detail to the work which Mr. Raman and I were engaged in last year on the planet. To night I fear I shall have to go over much of the same ground again, though perhaps in slightly greater detail, but with the advantage that there will be an opportunity for discussion on the points raised at the end of the paper.

My observations began in May and continued well into November when the planet was too near the Sun for further work. As the observations will be continued during the present year as soon as the planet is in a favourable position, my report to-night will be more or less a preliminary to further reports which I hope to be able to send in future. Being a somewhat inexperienced observer of Jupiter, at any rate with the telescope, the 5″ Cooke Refractor, I am now using, the early observations cannot have the same value as the later ones. To a new observer I may say that it takes some days, probably weeks, before one becomes familiar with the more or less permanent markings of the planet, in other words with its General Geography (to use an Earthly Expression), with the rate of Revolution, and to know when to expect certain prominent markings. When this experience is gained then the observations become valuable.

For the purpose of determining the exact revolution of any spot or belt ending or beginning, my observation lack value to some extent because their exact time of transit over the Central meridian was not taken, though in November I did take a few definite transits of the Great Red Spot and the preceding end of the S. T. D. All I did last year was to take two or three drawings each night and to note the exact Standard time. In future whenever possible, I shall, in addition to taking drawings, note the time when certain spots or prominent features transit and then the rotation periods can be worked out with the greatest accuracy specially if taken over a long period of several weeks or months. However, even as it is by taking two drawings, with the same spot in the same position with reference to the Central meridian, and over a period of two or three months it has been possible to calculate the rotation periods of end spots with a degree of accuracy quite surprising. Errors of time and position become almost eliminated when taken over such periods and

already it has been possible to work out the rotation period of several spots to within one or two seconds.

Many of the spots, some black, some white, appear only once. They are not present when next the same portion of the planet presents itself. Some spots persist for days, even weeks or months, though they may change in appearance and size and even colour during that period. The general appearance of the belts and zones are more permanent though these also are subject to change. The most permanent object in the planet is the Great Red Spot. This with periods of faintness and brightness has maintained its size and general appearance since 1878 when it was discovered and it is possible it was visible many years previous to this date.

It is impossible to refer to all the detail on the planet as seen with a good telescope from night to night. On an exceptionally good night the detail is enormous and the markings are so delicate and elusive that it is impossible to reproduce them on paper and still more impossible to photograph them. Jupiter is essentially the planet of the amateur.

The best that photography can yet do is but feeble compared with the wealth of detail a good telescope of 4″ or even 3″ aperture reveals.

The following is a list of the most striking of the isolated spots seen during the period under observation :—

Date.	St. time.	Nature and number.	Position.	General remarks.
17-5-13	10-45 P.M.	4 black, rectangular	S. Edge of N. E. B.	Second spot on central meridian.
...	11-30 P.M.	3 black, rectangular	Ditto	Second spot in transit.
...	1-30 A.M.	3 Ditto	Ditto ...	P. end of second spot in transit.
...	1-30 A.M.	2 Ditto ...	S. Edge of S. E. B. .	F. end of first spot in transit.
19-6-13	9-30 P.M.	3 black, rectangular .	S. Edge of N. E. B.	P. end of third spot in transit.
21-6-13	9-30 P.M.	2 black, rectangular	S. Edge of N. E. B.	
26-7-13	10-0 P.M.	1 black ...	Within N. E. B.	
28-7-13	10-15 P.M.	7 faint, black	S. Edge of N. E. B.	
1-8-13	9-0 P.M.	1 white, round	Within N. E. B.	
3-8-13	10-45 P.M.	2 faint, white round	Within N. E. B. ...	Just passed C. Mer.
12-8-13	10-30 P.M.	1 long, thin black	Within N. E. B. ...	In transit.
22-8-13	8-30 P.M.	1 large, white ...	Within E. Z. under F. End of S. T. D.	In transit.
25-8-13	8-40 P.M.	1 white-circular ...	Within N. E. B. ...	Just passed, C. M.
3-9-13	9-15 P.M.	1 black, rectangular	Under F. End of S. T. D.	
5-9-13	10-15 P.M	Same spot ...	.....	On C. Merid.
21 10-13	5-30 P.M.	1 black, rectangular	S. Edge of N. E. B.	Approaching C. M.

It will be noticed that nearly all these isolated black spots occur in the N. E. B. The few isolated white spots noticed were also seen in the same belt and these are about the only definite markings seen in this region; the more active disturbances were all in the Sportion of the planet.

Great Red Spot.—This was the most striking feature on the planet. It is found on the red S. E. B. It is elliptical (or somewhat pear-shaped to be more accurate, the pointed portion being towards the direction of revolution) in shape and of enormous dimensions, being some 24,000 miles long from E. to W. and some 7,000 miles broad from N. to S. It has been regularly observed since it was discovered by Pritchett of Glasgow Missions, U. S. A., in July 1878. In 1879 it attracted much attention and again it was brilliant in 1892. It seems to have periods of brightness and faintness, but whether there is any regularity in these periods or not, has not yet been determined. Last year, however, it was easily seen in small telescopes and in my 5″ was a striking object.

Its backward drift.—This is an undoubted fact. To determine this we must compare it with some permanent spot or feature. There is fortunately a permanent bright band in the S. E. B. known as the S. Tropical Disturbance. This band does not entirely surround the planet and between the two ends, the G. S. is situated. Now it is a fairly easy matter to compare the position of the spot between these two ends.

I have 35 drawings in which this spot figures and from an examination of these it is easy to see the spot has drifted backwards through any considerable distance. Take the two drawings 19th June and 8th November. The p. end of the S. T. D. is in the same position in both cases. In the former drawing, however, the spot is only partly visible, while in the latter the outline is easily in the picture. But proof of the drift does not depend on two drawings, all the drawings from the same phenomenon.

Its Repulsive force.—Invariably I have noticed that immediately round the spot there is a sort of white border (difficult to sketch) and that the darkness of the belt shades off in the neighbourhood. As far back as 1879 Barnard called attention to this repulsive force in the E. M. He noticed that the belts on the N. and S. sides of the ellipse bulged out and there was a sea of light almost completely round the spot. My drawings confirm his observations.

Its attractive force. The Black spot in the S. E. B.

Spot slides.—This spot, black, long and rectangular in shape, possesses great interest. On the 1st August it was near the F. end of the S. T. D. Altogether I have 16 drawings of this particular spot, and these prove without doubt that it travelled backwards in the direction of the Red Spot in which it was finally absorbed. It preserved its length until it was almost in contact with the ellipse, then it gradually shortened, became fainter and fainter, until it entirely disappeared. On the 12th October the spot was close to the ellipse apparently touching it. On the 17th October it had disappeared. Later observations confirm this. From the 1st August up to 30th September when it was seen practically in contact with the ellipse, it had drifted backward some 17,000 miles, or at the rate of 300 miles a day. That it was attracted and not merely drifted, appears to be shown by the fact that when it reached the G. R. S., there it stuck, became fainter and fainter and at last disappeared. It appears therefore certain that the lesser black spot was entirely swallowed up by the greater.

Notch (1).—With reference to this notch seen on the S. edge of the S. E. B. on the 17th July, 11-30 P.M., and followed until 1-30 A.M. the same night, Mr. Raman and I have tried to identify it with the notch or swelling to be described presently, but we have failed. It was evidently a separate phenomenon. Unfortunately the weather was bad in late May and early June and further observations were impossible here. It would be interesting to know if any other member observed Jupiter at this time and under better conditions.

Swelling and Gap.—On the 23rd August I noticed a curious swelling in the same narrow band as the notch previously described. My observations may be summarised thus—

Date.	St. time.	Description.	Remarks.	Position with reference to C. Meridian.
23-8-13	11-35 P.M.	Swelling ...	Sno. observer ...	Half way between E. Edge and C. M.
26-8-13	8-40 P.M.	Swelling ...	Sharp ...	On C. Merid.
4-9-13	10-10 P.M.	Swelling ...	Definition good, not very easy to see. Dark shadow above.	Approaching C. M.
5-9-13	6-35 P.M.	More like faint gap	Good Def. ...	Near C. M.
9-9-13	10-0 P.M.	Gap Square Ends ...	Def. fair ...	On C. M.
12-9-13	6-35 P.M.	Gap only faint ...	.....	Approaching C. M.
24-9-13	6-40 P.M.	Gap faint ...	Rectangular ... Def. not good.	Do.

Date.	St. time.	Description.	Remarks.	Position with reference to C. Meridian.
26-9-13	8-30 P.M.	Gap rect. in shape	.....	Approaching C. M.
13-10-13	7-20 P.M.	Gap widening ...	Def. good ...	Do.
18-10-13	6-5 P.M.	Gap wider ...	Def. good ...	Do.
21-10-13	5-30 P.M.	Gap ...	Def. good ...	Approaching W. Edge.
23-10-13	5-30 P.M.	Gap widening slowly	Clear. Easy to see ...	Approaching C. M.
25-10-13	7-0 P.M.	Gap much wider ...	Fair def. ...	E. of C. M.
30-10-13	6-5 P.M.	Gap very wide—Double 23-8.	Def. very good ...	Approaching C. M.
4-11-13	5-45 P.M.	Gap quite double 23-8	Def. good ...	On C. Merid.

The gap is quite twice as wide as on 23rd August. It will be well to remember this when we deal with the question of the condition of Jupiter's surface.

Notch (2)—Position on S. edge of S. E. B. immediately preceding p. end of S. T. D.

Date.	St. time.	Definition.	Description.	Position as regards C. M.
23-8-13	9-50 P.M.	Good ...	Deep and narrow ...	Approaching C. M. (very near).
4-9-13	7-20 P.M.	Poor ...	Not well seen. Same position.	Approaching C. M.
6-9-13	9-45 P.M.	Fair ...	Sharp ...	Just passed C. M.
9-9-13	9-9 P.M.	Good ...	Sharp. Slightly longer	On C. M.
23-9-13	8-30 P.M.	Fair ...	Faint ...	Just passed C. M.
15-10-13	6-0 P.M.	Fair ...	Faint. Somewhat drawn out.	Approaching C. M.
20-10-13	6-5 P.M.	Good ...	Long drawn out hollow.	Near W. Edge.
22-10-13	7-0 P.M.	Good ...	Very long drawn out & shallow.	Approaching C. M.
27-10-13	5-30 P.M.	Poor ...	Very difficult to see. Only long shallow hollow.	Approaching C. M.
1-11-13	5-20 P.M.	Fair ...	Very long slight hollow.	
3-11-13	6-15 P.M.	Fair ...	Resembles 1st Nov.	
8-11-13	5-24 P.M.	Good ...	Very long hollow, practically original notch disappeared.	

Belts and Bands.—
As a rule the belts are fairly straight and parallel to each other, but several times I have noticed that the band above the Red Spot, or above the S. T. D. swells or bulges out. This fact has been referred to previously.
3-8-13 The R. S. caused the S. E. B. to bulge out.
25-8-13 The F. End of the S. T. D. caused the same belt to bulge.
3-9-13 The same occurs as on 25-8-13.
1-11-3 Resembles 3-8-13.
Again the fainter S. temperate band sometimes bulges.
8-11-13 Here this is very noticeable.

I have not given much attention to the Belts and Zones N. & S. of the S. E. and N. E. Belts as they are rather faint, but on good nights Belts and Zones can be seen N. and S. up to 75° latitude.

I have already referred to the fact that most of the isolated black and white spots are found in the N. E. Belt. I have nothing more to say with reference to this Belt.

S. E. Belt.—This is perhaps the most important Belt on the planet. It is dull red in colour and when seen side by side with the dazzlingly white Moon at a time of occultation it is strikingly ruddy. It is in this region that the great spot is situated and here also the S. T. D. occurs.

On the E. of the G. R. S. a bead like arrangement of small white spots has been seen, *e.g.*, 25-8, 26-8, 4-9, 9-9, 23-9, 13-10. But perfect nights are necessary. Mr. Raman has seen more details herewith his 7″ merz. than I have with my refractor.

Further between the G. R. S. and the p. end of the S. T. D. I have invariably noticed a light band running up from the lower E. end of the R. S. to the S. T. D. This light area is a feature of almost every drawing where the R. S. comes in. A similar band though not so striking is seen between the F. end of the S. T. D. and the Red spot.

The S. T. D. is on the whole wonderfully stable being long and narrow with rounded meniscus-like ends resembling a thick column of Mercury. The band is, however, not quite stable. On the 20th October I noticed a notch in the N. side of the p. end and this notch persisted until October 30th when it disappeared. Occasionally also I have noticed that the N. edge is slightly jagged.

A rather striking feature of the S. E. Belt, but only the portion under the S. T. D. is that it is divided into two portions throughout its whole length by a light narrow band. This is a permanent division but not always easy to see.

Widening of the S. E. Belt.—

Up to 30th September the S. E. B. and the Eg. Zone were about equal in breadth, but after this a change set in; the S. E. B. gradually became wider until by the 20th October the upper half of the bright E. Zone was entirely absorbed into the S. E. B. The portion of the E. Zone thus taken in is not continuously black however, it is frequently seen to break up into long drawn out ellipses. These were a very striking feature of the planet in the latter part of October

and early November. These ellipses are very common but they vary with every revolution of the planet.

Eq. Zone.—This is a most active area for differential movements are going on here right the planet. The most striking feature is the fairly regular system of arches with their bases pointing N. This arrangement can be seen at any position of the planets in the course of its revolution. The pillars of the arches are generally vertical, but they are often tilted sometimes to the left and occasionally to the right. Sometimes two arches coalesce into one large arch though the middle base remains. At the lower part of each pillar is invariably a black rectangular spot or base. These arches were a most striking feature from July to November.

A Note on Mira Ceti.

By Miss M. C. Feline.

It had long been my desire to see for myself Mira, the "wonderful," but not till this year have I been able to do so. Possibly this account of Mira (imperfect though it is) may be of some interest. The opportunity of watching it night after night was an exceptionally good one as our verandah faces West and gives an unbroken view to the horizon.

It was about the 1st or 2nd of February that I first discerned a very dim Star in the place where Mira should appear. Throughout the month I observed it slowly brightening till by the end of the month it was comparable in brightness to γ and ζ Ceti,—about the 4th magnitude.

From March 14th I kept a detailed account till the time when last visible on March 26th.

I had already watched it without intermission each night but hitherto had no thought it could possibly be of use till suggested to me by a friend.

From that time I noted each night's appearance (or non-appearance) thus :—

March 14th & 15th	... Obscured by clouds.
,, *16th*	... As bright as α Ceti. (3rd magnitude.)
,, *17th*	... Clouds again.

March	*18th*	... α Ceti and β Arietis.
,,	*19th*	... α Ceti.
,,	*20th, 21st & 22nd*	Clouds.
,,	*23rd*	... ν Ceti (4th magnitude).
,,	*24th*	... Visible, but no comparison possible owing to luminosity of western horizon and thickness of atmosphere.
,,	*25th*	... γ Ceti.
,,	*26th*	... γ Ceti.

By this time the Star became too low for any certain comparison, as the decreasing brightness might be due to the Sunset light in which it was obscured, but it seems as though the maximum had in reality been reached, in which case it never appeared brighter than a star of 3rd magnitude.

The Orbits of Celestial Bodies, as Elliptical, Parabolic and Hyperbolic Plane Curves.

By Revd. A. C. Ridsdale, M.A., F.R.A.S.

Newton proved in his Principia, that any body which moves around its centre of attracting force, in a manner such that the attraction is always in the inverse duplicate ratio of its distance from that centre, must describe a plane conic curve. And conversely, if any body is found moving round another in a conic curve, the force which effects its motion must be that of the "law of the inverse squares" or gravitation. So long, however, as a body obeys this law of the inverse squares of the distance, it is free to move round the Sun at any distance, in any plane, in any direction, and in any conic orbit. It may describe an elliptical curve, which may be of any eccentricity, ranging from a perfect circle to an extremely elongated oval. And it may be in any plane, and the body may be moving in any direction. Again, a body moving under the law of inverse squares or gravitation, may not be moving in an ellipse at all, but in a parabolic curve. And although the parabola has only one shape, yet it may be of any size, and the perihelion distance may vary to any extent, as also its direction and plane. Again the body under this law of gravitation, may be travelling in a hyperbolic curve, and the hyperbola may vary not only in

plane, and direction, and perihelion distance, but also in shape. The planets move in elliptical orbits, making complete revolutions in equal periods of time, but varying in velocity in each revolution, whilst the triangular areas remain constant. Let us see why areal velocity is constant, whilst linear velocity is variable. The areal velocity, or triangular areas described by the radius vector joining points plotted at equal intervals on a straight path to a point without it, will obviously be equal, since the triangles will all be on equal bases and between the same parallels. Again, any impulse along the line of the radius vector cannot alter the magnitudes of these areas. And the continuous central force acting upon the circulating body is merely equivalent to an indefinite number of separate impulses along the line of the radius vector. And hence the areas swept out will still remain invariable in equal periods of time. Again since the triangular area per unit of time is constant, and is $= \frac{1}{2} \times$ distance travelled in a unit of time $\times$ distance from focal centre, therefore, since in any conic except a circle the distance from the focal centre varies, the distance travelled in a unit of time, or the velocity, must also vary. The planets' ellipses differ in eccentricity and in orbital plane, and perihelion distance, but not in direction. When the period of any planet is known, we can find by a simple process its distance, and *vice versa*. This is the Harmonic law, which Kepler enunciated, *viz.*, that the squares of planets' periods are proportional to the cubes of their distances. Thus if we know the period of a planet to be twice that of the Earth its distance will be $2^{\frac{2}{3}}$ or $3\sqrt{4} \times$ the Earth's distance. If again a planet's distance is known to be twice that of the Earth, its period will be $2^{\frac{3}{2}}$ or $2\sqrt{8} \times$ the Earth's period. This method, however, owing to the disturbing influence of the planets upon one another, can only give approximate results. The whole matter of the planetary orbits is a question of two opposite and equal forces. The one force is the tendency of bodies to come together, and the tendency is proportional to the product of the masses of the 2 bodies, and inversely proportional to the duplicate ratio of their distance apart. This is the gravitational force. The second force is the tendency of a body to escape away from the attracting body in a straight line tangential to the point of its orbit. This latter is the centrifugal force, and is proportional to the square of the velocity of the circulating body, and inversely proportional to its distance from the attracting body. These 2 forces then, the gravitational and centrifugal forces

must balance each other. Thus if we take the case of a circular orbit the gravitational or central force G will be constant, and will be equal to the (velocity)^2 divided by the distance. Thus $G = V^2/d$. G is the central force measured as an "acceleration." A more convenient formula than the above, however, is one in which for V^2 (a quantity which is not given by direct observation) is substituted its equivalent, viz. :—$4\pi^2 d/t^2$. Thus $G = 4\pi^2 d^2/t^2 \times \frac{1}{d} = 4\pi^2 d/t^2 = 4\pi^2 \left(\frac{d}{t^2}\right)$

This central force G will then balance or $= 4\pi^2 \left(\frac{d}{t^2}\right)$

But G or the central force is the mass divided by the square of the distance, or $\frac{M}{d^2}$. Hence if we equate the two values of G, we get, $4\pi^2 \left(\frac{d}{t^2}\right) = \frac{M}{d^2}$ and $t^2 = \frac{4\pi^2}{M} d^3$. And $\frac{4\pi^2}{M}$ being a constant quantity we get the Harmonic law or Kepler's 3rd law, viz., that t^2 is proportional to d^3. Now when a second force draws a body aside out of its natural course in a straight line, it is able to do so by just as great an amount as if the attracted body had not been originally moving at all. And hence the circulating body may be represented as moving along the diagonal of a parallelogram, one side of which will represent in velocity and direction the path the body would have taken if undisturbed in space, and the other side the velocity and direction it would have taken had the only force acting upon it been the attracting force from the centre. Thus conversely, the motion of the circulating body may be resolved into two directions and velocities in any unit of time, represented by the 2 sides of this parallelogram, whose diagonal is its actual path. We noticed that centrifugal force in a circle = velocity squared divided by the distance, And the Sun's attraction is his mass divided by his distance squared. That the Sun's gravitational attraction upon bodies circulating round him is inversely proportional to his (distance) can be seen from the following. We have shown above that $G = 4\pi^2 \left(\frac{d}{t^2}\right)$, and $G^1 = 4\pi^2 \left(\frac{d_1}{t^2_1}\right)$.

Hence $G/G^1 = \frac{d}{t^2} \times \frac{t^2_1}{d_1}$. But $t^2 : t^2_1 = d^3 : d^3_1$ Hence $t^2_1 = t^2 d^3_1/d^3$ and hence $G/G_1 = d^2_1/d^2$ and therefore $G : G_1$ as $d^2_1 : d^2$, that is the Sun's attraction is in the inverse ratio of the square of the distance. And for circular orbits (and the orbits of the planets are nearly circular)

the centrifugal force must always balance exactly the gravitational force. For circular orbits, the body must be projected at a certain definite velocity (which we will discuss more fully later on), and it must also be projected at right angles to the radius vector joining it to the Sun. If the (velocity)^2 of projection be more than the circular (velocity)^2, the orbit will be an elliptical curve. If it be exactly twice the circular (velocity), the orbit will be a parabolic curve. If the (velocity)^2 be still greater than twice the circular (velocity)^2, the orbit will be an hyperbola. Now, in order to find the character of any particular conic, that is, whether it be an ellipse, parabola or hyperbola, it is necessary first to find its major axis. And the semi-axis major of the conic is determined by the equation $V^2 = M\left(\frac{2}{d} - \frac{1}{a}\right)$. For if V (velocity), M (mass), and D (distance) be known, then we can find $2a$ (the major axis) which is $2M\left(\frac{d}{2M - d\,V^2}\right)$. And since in an ellipse the two focal radii together = major axis, we can find the magnitude of the second focal radius d, by subtracting the known d from $2a$, and we can also find its direction by making its tangential angle equal to the tangential angle of the known focal radius d. If the conic be an hyperbola a will be a negative quantity, and in order to find d, in this case, we must make $d = 2a + d$, measuring it off on the other side of the line of motion, that is backwards or on the other side of the curve, and in a direction which will make its tangential angle = that made by d. Whether it be an ellipse or an hyperbola, the second focus can thus be found. The line drawn through the foci will be the line of apsides, and the point midway between the foci will be the centre. Thus having found the position of the 2 foci, and the magnitude of the major axis, we can trace out the conic curve. Now if a particle falls towards an attracting body, whose mass is M, from one distance p to another distance d, then its (velocity)^2 will be $2M\left(\frac{1}{d} - \frac{1}{p}\right)$. And if the difference between d and p be called h, then $V^2 = M\left(\frac{1}{d} - \frac{1}{d+h}\right) = 2M\left(\frac{h}{d^2 + dh}\right)$. And if h be very small compared with d we have $V^2 = \left(\frac{2M}{d^2}\right)h$, and this expression is identical with that which gives the gravitational velocity at the Earth's surface, *viz.* $2gh$. Again, if the particle

come from an infinite distance, it will not acquire an infinite velocity until its distance from the Sun's centre become zero. The velocity from infinity for the distance d from the Sun's centre which is called the "parabolic velocity" is usually given as U which $= \sqrt{\frac{2M}{d}}$, or $U^2 = \frac{2M}{d}$, and hence $M = \frac{1}{2} d U^2$, and $d = \frac{2M}{U^2}$. From the first of these equations, it can be seen, that the parabolic velocity is proportional to the inverse sub-duplicate ratio of the distance from the Sun. The parabolic velocity at the Earth's distance from the Sun will be rather over 26 miles a second. At the distance of the furthest planet it will be less than 5 miles a second. At the Sun's surface it will be 383 miles a second. Again since $U = \sqrt{\frac{2M}{d}}$, the parabolic velocity varies in the sub-duplicate ratio of the mass. Thus if the Sun's mass were doubled, U would be increased in the ratio of $\sqrt{2}$ to 1. Again the velocity determines the character or nature of the orbit, that is to say, whether it be an elliptical, parabolic or hyperbolic curve. We have said above that $a = M \frac{d}{2M - dV^2}$ and again that $M = \frac{1}{2} d U^2$. Therefore $a = \frac{1}{2} d U^2 \left(\frac{d}{dU^2 - dV}\right) = \frac{d}{2}\left(\frac{U^2}{U^2 - V^2}\right)$. Now from the above equation, if V^2 be less than U^2, then a (the semi-major axis) will be a positive quantity, and therefore the curve will be an ellipse. In other words if the velocity of a body falling towards the Sun be less than that which would be acquired by a body falling from an infinite distance, then that body will not again quit the Sun, but will move round him for ever in an elliptical curve. If, however, V^2 be greater than U^2 in the above formula, a will be negative, and the orbit will be hyperbolic, and the body will quit the Sun for ever towards opposite parts of the heavens. If thirdly $V^2 = U^2$ the denominator will be zero, and will be infinite, and the curve will therefore be parabolic and the body will recede from the Sun in a direction nearly parallel to that whence it came. It is probable that no bodies move exactly in parabolic curves, since the slightest increase or diminution of their velocity would convert the parabola into an hyperbola or ellipse. From this same expression, $a = \frac{d}{2}\left(\frac{U^2}{U^2 - V^2}\right)$, it can be seen that where V^2 is constant and d is constant, or in other words,

when different bodies have the same velocity at the same distance from the Sun, their orbits (if ellipses or hyperbolas) will all have the same-sized major axis, whatever be their shape due to variations in direction of projection, and (if ellipses) they will all have the same period as well. If, however, at the same distance their velocities differ, of course their major axis will likewise differ in magnitude. Thus, for example, if $V2$ = unity = $U2$, then $a = \infty$ and the second focal radius = ∞ and the curve will be a parabola. If again $V2$ is (say) $\frac{3}{4}$ $U2$, then $a = 2$ and $d_1 = 3$, and the curve will be an ellipse. If $V2 = 2\ U^2$, then $a = -\frac{1}{2}$ and $d_1 = -2$, and the curve will be an hyperbola. We mentioned above that the parabolic velocity due to the Sun's accelerating force was 383 miles per second. But the parabolic velocity at the Earth's surface (that is, when $V = U$) is only 6·9 miles per second. A body moving at 6·9 miles per second then would quit the Earth in a parabolic curve. If the body's velocity were = $\sqrt{\frac{1}{2}}$ U = 4·9 miles per second and in a direction perpendicular to the Earth's radius, it would move round the earth in a circular orbit. If again its $V > U$ = > 6·9 miles per second, it would quit the Earth in a hyperbolic curve. The parabolic (velocity) varies directly as the mass of the attracting body. Thus at the surface of Mercury, it will be only 2·2 miles per second, at the surface of the Moon 1·5 miles, and at that of Jupiter as much as 37 miles per second. If bodies are to move in circular orbits, not only must their (velocity)^2 = $\frac{1}{2}$ the parabolic (velocity)^2 but their motion must be at right angles to the line joining them to their centre of attraction. In the case of the planets and their satellites which move nearly in circular orbits, these two conditions are nearly fulfilled. When the law of gravitation was first discovered, no other bodies except planets and their satellites were known to move around the Sun. The planets indeed obeyed perfectly this law of gravitation (after perturbations had been duly accounted for) but they did much more than obey it. The law of gravitation would allow bodies to move in any of the 3 classes of conic sections, in any direction and in any plane. But the planets move only in ellipses, and nearly in the same plane, and all in the same direction. And even their perihelion distances differ in an orderly progression. Bodies then that would illustrate this great law of gravitation in all its variety; bodies that would be found to move in each of the conics, in all directions, planes, and perihelion distances were yet to seek. These bodies are the comets. No sooner had the law of gravitation been discovered, than the astronomers and

mathematicians set themselves to see if the law could not be illustrated by their motions. Up to this time comets had been regarded as "portents," obeying no laws of nature. It was not even known whether they were cosmical or merely meteoric phenomena—whether, in other words, their paths lay in infinite space or merely in the upper atmosphere of our Earth. Their appearances in the past had indeed been recorded, but without the precision necessary to deduce any mathematical laws of their true motions. It was not till exact observation had been taken after the promulgation of the law of gravity, that the principles of cometary orbits were completely established, and their orbits shown to be in entire accord with the principles of gravitation. Other comets appeared, and they all confirmed this great discovery of Newton. His mathematical demonstrations were entirely corroborated by observation, and it was satisfactorily established as a scientic fact that the comets move in conics. But what conics? The geometrical form of an orbit will depend upon two things. The initial velocity of the body, and the distance from the Sun. We will neglect for the present, for simplicity's sake, the *direction* of the initial velocity. A certain velocity at a certain distance produces a circular orbit. A greater velocity an ellipse. The ellipse will increase in eccentricity until the velocity $= \sqrt{2} \times$ the circular velocity. At that point the ellipse, which has been increasing in eccentricity (and whose major axis has been lengthening and has at the last stages been lengthening at an enormous rate) will suddenly assume the form of a parabola, a curve with infinite branches and major axis of infinite length, and centre at an infinite distance. A body whose velocity is "parabolic" when at perihelion, must be a body which has come from an infinite distance in space, and will return again into infinite space. It could not then form part of the Solar system, but must be only a temporary visitor. And unless its parabolic orbit were sufficiently interfered with by the planets which it will have to pass as it issues from the Solar system, it will never be seen again by us. Next let us consider the case of a body moving with a velocity still greater than "parabolic." It will then describe an hyperbola. Its curve will still be one of infinite branches, of which the Sun will be as before one of the foci, but it will depart from the Solar system in a direction quite different from that in which it entered the region of the Sun's influence. The two branches of the parabola on the other hand tend to become more and more parallel to the major axis, whilst they never become actually parallel, much less can they ever converge.

They therefore never reunite, but when at a distance from the focal centre which is indefinitely in excess of the perihelion distance, their direction is practically parallel. Since parabolas are all of the same shape, the distance between these 2 parallels is proportional to the perihelion distance. There is of course no such thing as periodic time for a body moving in a parabola. It will enter the Solar system in a definite direction from an indefinite distance, and as it enters within the sphere of Solar attraction, its path which before was practically in a straight line will begin sensibly to bend, and its curvature will become greatest at the point where it approaches nearest to the Sun. But such is its velocity that its inertia carries it once again in a direction away from the Sun. As it recedes, its path again becomes gradually less curved, and continues in almost a straight line again to infinity, in a direction parallel to that along which it entered the Solar system. The conduct of a hyperbolic body is very similar to that of a parabolic body, except that as we have said it comes and goes in quite different directions. It is not easy to decide what is the particular conic in which a body is really moving. Whilst the almost circular orbit of a planet can be traced and observed almost throughout its whole period, the parabolic or hyperbolic or even the elliptical path if it have a considerable eccentricity cannot be observed except in a comparatively very small arc of its orbit extending only a little distance on either side of perihelion. In general this arc in which alone the body will be visible, will not be greater than the portion which is bounded by the latus rectum or parameter. The orbits of comets are usually very long ellipses, *i.e.*, ellipses whose excentricity is very nearly equal to unity, or in other words they approach the parabola. As then comets remain visible for only a very small portion of their whole orbit, soon getting beyond the reach of the most powerful telescopes, it is no easy matter to determine from this very small arc, exactly to what form of ellipse the body belongs, or even if its orbit may not be parabolic or even hyperbolic, of the same perihelion distance, since these curves cannot vary much within so small a perihelion arc. If it be determined, however, from observations of the visible arc that the curve of the body's path is re-entering, or elliptical, then the invisible part can be inferred from the visible, and the major axis can be found. The body will of course then be periodic, and the time of its period can be found from the length of its major axis. It will then not be an occasional visitor, but as permanent a member of the solar system as a planet. However the smallness of the

visible arc, as I have said, makes it extremely difficult to determine whether the orbit be an elliptical, parabolic, or hyperbolic curve. In fact the only absolute proof of an orbit being elliptical is that the body returns, or in other words is periodic. Hence it will be inferred that the body had passed perihelion in former times and will come again to perihelion in the future in equal intervals. Consequently searches are made in the records for former appearances of such a body. If such a body were not affected in its orbital path by any other attraction than that of the Sun's central gravitational force, it would always reappear at the exact interval, at exactly the same distance, would always trace out exactly the same visible arc, and would move in exactly the same plane, inclined at the same angle to the ecliptic, and having its nodes in the same position. This exact punctuality and regularity, however, in the periodic returns of cometary bodies cannot be expected, because their elliptical paths being very eccentric, they necessarily cut clean across the paths of many of the planets (and sometimes issue to a vast distance out beyond Neptune), and therefore their paths and periods are to some extent modified by the disturbing interference of the planets. However, such is the predominating central influence of the Sun, that such perturbations cannot ordinarily be very considerable. But most of the comets have so eccentric an ellipse, that they do not reappear at perihelion for many hundreds, nay thousands, of years. It is therefore even in the case of true elliptical comets extremely difficult in most cases to establish for certain that their paths are elliptical, and not parabolic. Even with the most refined modern instruments of observation, it is a matter of the utmost delicacy to calculate the exact path of the body. Newton was the first to conceive a method for simplifying orbital calculations, by assuming the path in the first instance to be parabolic, since the parabola is easier than either the el ipse or the hyperbola to compute, and as a matter of fact, a cometary path never lies very far on one side or the other of the parabolic curve. The method of determining a parabolic orbit is as follows. First the true position of the plane of the parabola which passes through the centre of the Sun must be determined. And this is done, by determining the line of intersection where it cuts the ecliptic, and secondly, its inclination to the ecliptic. The line of nodes of the parabola will pass through the Sun. It is sufficient to know one only of the two nodes, generally the node where the body passes from South to North of the ecliptic plane. Its position is given by the angle it makes at the Sun with the First Point.

of Aries, or in other words its longitude. The next element is the inclination of the parabolic plane to the ecliptic (the fundamental plane of reference), which is the angle the 2 planes make with each other at the nodes. Now we have found the position of the plane. It remains to fix the actual curve in space. First we must know the perihelion distance, and secondly the longitude of the pericentre.

Then the vertex of the parabola will have been completely found. Next we must find the direction of the body's motion. For this purpose the plane of the parabola must be projected upon the plane of the ecliptic, and if the motion be from West to East like the motion of the Earth, it will be direct, and *vice versa*. The last element to be ascertained is the exact date of the perehelion passage. Thence its position at any future time can be determined (since its areal velocity is constant) from the fact that the portion of the area traversed by the radius vector during time t will be in the same ratio to the whole area of the ellipse as t : T (the periodic time). From these elements all the necessary data of time and space can be mathematically calculated. At least 3 accurate observations of the body are required before these elements can be determined. More than 3 observations are not absolutely necessary, but extra observations may be of great practical service in verifying the results of calculation; or in other words of observing whether the body does in fact accurately keep to the curve plotted out for it by the ephemeris. If it do not, and if the observed path differ from the calculated parabolic one, by an amount that is too great to be attributed merely to errors of observation, then we must conclude that its path is either elliptical or hyperbolic. Most of the orbits that differ from the parabolic are elliptical, and hence most bodies will return periodically to perihelion, and are therefore true members of the Solar family. Others are not, and have hyperbolic orbits. Others have elliptical orbits indeed, but of so great eccentricity, as to be practically non-periodic. Thus the comet of 1780 had appeared at perihelion previously to that occasion no less than 75,840 years before, and the comet of 1844 will not reappear for another thousand centuries to come. These comets in spite of the immense eccentricity of their elliptical paths are however, true members of the Solar system. They do not indeed travel out into space as much as one-fiftieth of the distance of the nearest Star (it must be remembered that even from the nearest Star Alpha centauri it takes light, which travels at 186,330 miles a second, over 4 years to reach our Earth), and consequently the Sun will always remain for them the chief

attracting force governing their motions. The method of computing an orbit has been greatly improved and simplified by more recent mathematicians, especially G. F. Gauss, whose monumental work "Theoria Motus Corporum Cælestium" is still the great authority on the subject. But it is still a matter of considerable difficulty and complexity. Now-a-days, after the first approximate parabolic orbit has been found, an ephemeris is drawn up, with which the daily observed positions of the body during its period of visibility are compared. If as we have said the observations do not agree with the theoretical calculations, it remains to examine whether the orbit be hyperbolic or elliptical. If as is generally the case the orbit proves to be elliptical, two more elements beyond those required for a parabolic orbit have to be found. Those are first, the eccentricity, which together with the perihelion distance gives us the major axis, and secondly, the length of the period of revolution, which can by means of the harmonic law be found from the major axis. The periodicity of a comet can be judged not from its appearance, which is very changeable, but from the elements of its orbit. If the longitude of perihelion and the nodes and the perihelion distance and the inclination and direction are the same (or nearly the same—since allowances have to be made for planetary disturbances) as observed on a former occasion, the chances are it is the same comet returned once more, and its next return to perihelion can be accurately predicted. The first certain proof of the periodicity of a cometary body, *viz.*, its return in accordance with prediction, meant the triumph of the Newtonian theory of gravitation, over all the other theories hitherto put forward to account for the celestial motions, in a word, that the celestial bodies under the "law of the inverse squares" necessarily trace out about their centre of attraction elliptical, parabolic, or hyperbolic plane curves. We will next turn our attention to the orbits of those celestial bodies which we call meteors. It is now known that they pursue regular elliptical orbits around the Sun. The velocity with which the meteoric bodies enter the Earth's atmosphere is found to be a little less than 26 miles per second, which is a little less than the parabolic velocity for bodies at the Earth's distance from the Sun. This velocity is similar to that of elliptical comets. The earth Encounters them periodically, whenever its path intersects that of the meteoric Swarm. Thus of the three chief Swarms, the Leonids and Andromedes come in contact with the Earth in November, and the Perseids in August. The Leonids circulate round the Sun in an opposite direction from the

Earth's motion, and therefore appear to us to have a motion much swifter than the Perseids and Andromedes which move in the same direction as the Earth. Olmsted in 1833 proved that the orbits of certain comets were identical with those of meteoric Swarms, and Erman a year later showed these Swarms were distributed as elliptical rings all or most of the way around their orbits. These meteoric rings are formed of an almost infinite number of individual ellipses (massed or tangled together) traced out by each meteoric body separately. We may naturally conclude then that a comet the elements of whose orbit are identical in magnitude shape and position with the average meteoric ellipses, would be one of the constituent members of the meteoric Swarm or ring. The great mathematician Adams made out a very laborious and complete computation of the orbit of the autumn meteorites as affected by planetary perturbation. He found that there was a slow motion of its nodes of 52″ a year. Thus the Arab Chronicles in complete accordance with Adam's calculations, give the date of contact with the Earth of this Autumnal meteoric shower in the year 90 A.D. as occurring on October 19th, whereas the modern date is November 12th. Schiaparelli in 1866 proved that the Perseids were moving in the same path as Tuttle's comet of 1862. Leverrier again showed that the Leonids' orbit was identical with that of Tempel's comet of 1866. In 1872 the Andromedes were seen to be moving in exactly the same orbit as Biela's comet of the previous year. The elements of the orbit of the Perseids (or August meteors) is as follows. The sidereal period is $13\frac{1}{2}$ years. The perihelion distance is unity. The aphelion distance is $10\frac{1}{2}$. The eccentricity is $\frac{4}{5}$. The longitude of its perihelion is about $116\frac{1}{2}°$, and that of its ascending node about 270°, and its inclination $54\frac{1}{2}°$. The Andromedes (or November meteors) have an orbital period of $6\frac{1}{2}$ years, perihelion distance 0·8, aphelion distance 6·2, eccentricity $\frac{7}{17}$, longitude of perihelion 110° and that of the node 245° and inclination $12\frac{1}{4}°$. Leverrier showed that the Leonid meteors must have passed (no doubt in a hyperbolic or parabolic orbit) very near Uranus in A.D. 126, and that they were then drawn into our Solar system by his attraction, and henceforth made to perform an elliptical orbit round the Sun in a direction opposite to that in which they entered the Sun's sphere of influence. The Leonids' present orbit is, period $6\frac{1}{2}$ years, perihelion distance 2, aphelion 5, eccentricity $\frac{2}{5}$, inclination nearly 11. A paper on the orbit of celestial bodies would be wholly incomplete, if we omitted all mention of the orbits of the Sun and the Stars. Let us begin with the

Sun's motion. It can be easily calculated that the Sun's motion, as seen from a sixth magnitude star, would be ·05 seconds of arc in a year. We could say how many miles a year that amount would be equivalent to, if we knew exactly the distance of a sixth magnitude Star. The probable distance (judging from the fact that star-light varies in the inverse ratio of the square of the distance) is 20,000,000 × the distance of the Earth from the Sun. And if this estimate is correct, the Sun's velocity will be 15 miles per second. This represents the Sun's motion as a transversal or "proper" motion. But the spectroscopic analysis of radial motion makes the Sun's velocity to be only 11 miles per second. The true velocity then of the Sun's motion in space is probably something between 11 and 15 miles a second. The question for us then is whether the Sun's motion of say 13 miles per second is an orbital or rectilinear motion. And precisely the same question applies to the Stars as well. Now the Stars with the exception of those that are of the same group or family, are acted upon by forces of every variety of power and direction. And since these forces must in general pretty nearly balance one another, the resultant attraction upon any individual Star (and the Sun is but an individual Star) cannot be very great or very permanent. The Stars consequently move in the main in broken rectilinear directions. As the resultant balance of attractions, however, will seldom or never be exact, the paths of the Stars will not be exactly rectilinear at any time, but slightly curved, and as with change of position a Star will constantly meet with change in the power and direction of attracting forces, its path will consequently be bent in various directions, and these directions will not be in the same plane. The curvature however of its path would probably be so slight that its change of direction could hardly be ordinarily observed in the space of hundreds or even thousands of years. In fact the stars in general doubtless move in no fixed mathematical curves. The question is, does the stellar universe form an organized system, in which the motions of the individual Stars have a definite and subordinate relation to that system? Do the laws of gravitation which obtain in the Solar system hold good for the whole stellar universe? We know from micrometric and spectroscopic observations that the Stars are moving with immense velocities,—are they governed without exception by the "law of the inverse square"? For it must be remembered that whilst their motions (so far as they have been ascertained) are quite consistent with the laws of gravitation, they could equally well be due to many other imaginable laws

of force. We can only say then for certain that if there be any central governing force at all for the stellar universe (such as the Sun is for the Solar system) it must needs be very slight indeed, and irregular perturbation rather than orbital regularity would appear to be the main principle which governs the motions of the Stars. It has been very generally held that the whole stellar universe possesses a slow rotation in the plane of the galactic circle. And such a general orbital motion would not be in the least inconsistent with the independent motions of individual Stars. Indeed there is high probability that such a general orbital motion exists. However, exact astronomy is not yet old enough for sufficient data to have been accumulated in order to draw any certain conclusions. With regard then to the paths of the Sun and individual Stars, we cannot as yet lay down any precise general laws. But when we come to pairs or groups of Stars, the case is wholly different. The orbit described by binary Stars are invariably found to be true ellipses, having their common centre of gravity at the focus. The ellipses described by the two Stars round one another are similar, and the magnitudes are in inverse proportion to the masses of the Stars. It is convenient for purposes of calculation to consider one of the two Stars as at rest and the other as circulating round it in a relative orbit. This relative orbit will be similar to the two real orbits, but its semi-major axis will be equal to the sum of the two semi-major axes of the real orbits. As a rule (except where there is a third independent Star in the same field of view from which we can measure the position, angles and distances of each orbit separately) the relative orbit is the only one we can deduce at present, being measured as it is by the varying distances and angular positions of the two Stars themselves. No doubt in time by the help of the spectroscope we shall be able to follow out the actual orbits of many double Stars which have hitherto baffled attempts at computation; so long as they are not too close together to allow of their spectra being examined separately We could then determine with great precision not only the form and size and position of the pair of Stars, but also their distance and masses. If the observer be in a position which is perpendicular to the plane of the binary orbit, he will see it as it really is, with the larger Star at the focus and the major and minor axes at right angles to each other. It will then be found that as the smaller Star revolves round the larger, it sweeps out equal triangular areas in equal periods of time, just as do the bodies belonging to the Solar system in accordance with the law of the inverse squares. If, however,

the observer be not in a position perpendicular to the orbit, the orbit will be seen distorted or in perspective. But even in the case of this distorted ellipse, although the larger Star will not be at the focus, and the major and minor axes will not be at right angles, nor will they represent the longest and shortest diameters of the ellipse, yet being still a true ellipse (for all projections of a conic are themselves conics) the smaller Star will still be observed to sweep out equal areas in equal periods. Five absolutely accurate observations are indeed sufficient to determine the relative orbit, but since even so small a quantity as 0·1 second of arc makes a large difference in such calculations, the observations must be exceedingly accurate, unless the orbit has been completed or very nearly completed, when in that case other matters enter in to help in its computation. Over sixty orbits of binary Stars have already been found and confirmed. Their periods range from eleven up to many thousands of years, and their angular semi-axis major range from 0·3 up to 18 seconds of arc, their real dimensions being known of course only when we also know their parallaxes. Thus in the case of Alpha Centauri, whose parallax is 0·75, and whose angular semi-axis is 17·7, its real semi-axis major will be $17{\cdot}7 \times \frac{100}{75}$ × Earth's distance from the Sun $= 23{\cdot}6 \times$ that distance. Again Sirius' parallax is 0·39, and the angular semi-axis major is 8·03, and therefore the real semi-axis major will be 20·6 astronomical units. The orbits of those binary Stars which have no measureable parallax, but yet give an equally large apparent semi-axis major, must be of still larger dimensions. The orbits of the sixty binary Stars at present known have ellipses of great eccentricity, averaging 0·6. This fact is probably due to the extremely powerful and effective tidal-reaction which would necessarily be set up between two bodies, which have separated from an original single nebulous mass. Besides binary or physically double Stars, there are triple, and multiple Stars, exhibiting all the permutations and combinations of orbital motion. Epsilon Lyrae, for example, is a pair of pairs. Each pair has a period of about four hundred years, and meanwhile pair revolves round pair in a period of many thousands of years. The case of Zeta Cancri is more complicated. Here we have two Stars at the mean distance of two seconds of arc apart revolving round each other in ellipses, and a third Star at a greater distance revolving round this pair, and at the same time showing by the peculiarity of the curve of its orbit, that it is also at the same time making a secondary revolution around a fourth

Star which is not bright enough to be visible to us. In Theta Orionis again we have a case of a large number of Stars, all physically connected, not moving in pairs, but in every variety of elliptical orbits around each other, presenting for the mathematician are almost insoluble problem of infinite complexity. The paths then of the Sun and of individual Stars in general can be represented by no known mathematical curves, whilst the paths of binaries or their multiples have so far been found to be invariably ellipses of great eccentricity. I have now tried to put before you the chief facts freed as far as possible from mathematical technicalities, relating to the orbits of celestial bodies, as elliptical, parabolic, and hyperbolic plane curves. We began by showing how Newton proved that all celestial bodies that are subject to the law of gravitation must be moving in plane conic curves, and that under this law great variety of motion was possible in regard to distance, velocity, position of plane, direction, etc. We showed why the areal velocity of bodies moving in conics must be constant, whilst their linear velocity must be variable, and how a body's mean distance can be computed from its period, and *vice versa*. We examined into the elements of the centrifugal and centripetal forces and saw how that they must balance each other, and proved this by taking a circular orbit, and thence showed why the harmonic law must be true. We explained how the motion of a body can be represented as moving along a diagonal of the 2 component forces, centrifugal and centripetal, represented by the 2 sides of a parallelogram, and thence showed why the centripetal force is in the inverse ratio of the Sun's distance. We next showed how the velocity determines the particular form of conic, and how it is possible thence to lay down an ellipitical, an hyperbolic, or a parabolic path for an observed body. We explained the meaning and use of the expression "parabolic velocity" or "velocity from infinity", and showed its different values at the surface of the Sun, the Earth, and the planets. We demonstrated that if the V^2 = parabolic V^2 or U^2, the orbit will be a parabola, and if $V^2 > U$, the orbit will be an hyperbola, and if $V^2 = U^2$, the orbit will be an ellipse. We saw that when different bodies had the same velocity and distance, their major axes and periods will always be equal, and that the values of the major axes and consequently the second focal radii depend upon the (velocity)^2 of the body when that quantity varies, and that in the case of the parabola they will both be infinite. We showed that when the law of gravitation was first discovered, no bodies were known

to move in any but elliptical curves, but that it was soon guessed and proved, that the comets illustrated movement in parabolic and hyperbolic as well as elliptical curves. We showed that a parabolic or hyperbolic body must have travelled from infinity and will never return again to the solar system, and we traced the various stages in the approach and recession of a body in a parabolic orbit. We showed how difficult it is to exactly determine the path of an ellipse of great eccentricity and noticed Newton's method for simplifying orbital calculation by assuming them to be in the first instance approximately parabolic, and we showed how to compute a parabolic curve, and to completely fix its position and that of all its elements in space.

We then discussed the elements of meteoric orbits, and showed they were rings consisting of a conglomeration of an almost infinite number of ellipses, traced out by individual meteorites. We showed how Adams, Schiaparelli and Leverrier in many instances had identified meteoric orbits with cometary orbits, and we gave the exact elements of the Leonids, Andromedes and Perseids. We next discussed the path of the Sun in space, and its direction and velocity, and the path of individual Stars and speculated upon the general motion of the Universe. We concluded that no fixed mathematical curves could represent these stellar motions. We next showed that in the case of binary Stars, their movements were in regular ellipses, and in several cases we gave the precise values of their orbital elements. We noticed the remarkable fact, that the 60 binary orbits which have so far been computed, without exception possessed great excentricity, and we attributed this to tidal-reaction.

Lastly we made mention of the more recent improvements in the methods of finding the nature of the various celestial orbits, that is, as elliptical parabolic or hyperbolic plane curves. Wonderful indeed is the perfection that has now been reached by purely mathematical processes, so that the vast conical curves of the paths of celestial bodies by reference to a system of co-ordinate axes can be accurately laid down years, and even ages, in advance.

Memoranda for Observers.

Standard Time of India is adopted in these Memoranda.

For the month of July 1914.

Sidereal time at 8 p.m.

		H.	M.	S.
July	*1st*	14	35	11
,,	*8th*	15	2	47
,,	*15th*	15	30	23
,,	*22nd*	15	57	59
,,	*29th*	16	25	34

From this table the constellations visible during the evenings in July can be ascertained by a reference to a Star chart, as the above hours of sidereal time represent the hours of Right Ascension on the meridian.

Phases of the Moon.

		H.M.
July 7th	Full Moon	7 30 P.M.
,, *15th*	Last Quarter	1 2 ,,
,, *23rd*	New Moon	8 8 A.M.
,, *30th*	First Quarter	5 21 ,,

Meteors.

	Radiant R. A.	Radiant Dec.	Character.
May—June—July	252°	— 21°	Slow ; trains.
June—July—Aug.	302°	+ 23°	Swift.
July 4th—14th ...	284°	— 13°	Very slow.
8th—20th ...	317°	+ 31°	Swift ; white.
July—August ...	279°	+ 57°	Slow ; short.
... ,, ,, ...	305°	— 12°	Slow ; long.
July 23rd–Aug. 16th	48°	+ 43°	Swift, streaks.

The Planets.

Mercury—Is an evening Star until the 16th when he will be in inferior conjunction with the Sun, and will then become a morning Star until the 30th of August. He will be visible for the first few days in the month when setting about an hour after the Sun.

Venus—Is an evening Star setting about two and a half hours after the Sun throughout the month.

Mars—Is also an evening Star. At the beginning of the month he will be close to Regulus in Leo, setting nearly four hours after the Sun. His position on the 15th will be R.A. 10·52, Dec. 8° 7′ North.

Jupiter—A morning Star, rises in Capricornus at about 9 p.m. at the beginning of the month. Position on the 15th R.A. 21·32, Dec. 15° 32′ South.

Saturn—Also a morning Star, rises in Taurus about an hour before the Sun on the 1st and nearly three hours before at the end of the month. Position on the 15th R.A. 5·41, Dec. 22° 14′ North, almost due north of Betelgeux.

Uranus—In Capricornus. Position on the 15th R.A. 20·52, Dec. 18° 17′ South.

Neptune—Is in conjunction with the Sun in Cancer on the 21st. Position on the 15th R. A. 7·59, Dec. 20° 15′ North.

For the month of August 1914.

Sidereal time at 8 p.m.

		H.	M.	S.
August	*1st*	16	37	24
,,	*8th*	17	5	0
,,	*15th*	17	32	36
,,	*22nd*	18	0	12
,,	*29th*	18	27	48

From this table the constellations visible during the evenings in August can be ascertained by a reference to a Star chart, as the above hours of sidereal time represent the hours of Right Ascension on the meridian.

Phases of the Moon.

August 6th	Full Moon ...	... 6 10 A.M
,, *14th*	Last Quarter	... 6 26 ,,
,, *21st*	New Moon ...	... 5 56 P.M.
,, *28th*	First Quarter	... 10 22 A.M.

Meteors.

	Radiant. R. A.	Dec.	Character.
June —July—August	... 302°	+ 23°	Swift.
July—August	... 279°	+ 57°	Slow ; short.
,,	... 305°	— 12°	Slow ; long.
July 25th—August 16th	... 48°	+ 43°	Swift ; streaks.
July 23rd—August 25th, 31st	339°	— 11°	Slow ; long ; brilliant.
August 10th—12th	... 45°	+ 57°	Swift ; streaks ; brilliant.
,, *10th—15th*	... 290°	+ 53°	Swift ; bright.
,, *21st—25th*	... 291°	+ 60°	Slow ; bright.
August—September	... 346°	+ 1°	Slow.

The Planets.

Mercury—Is a morning Star until the 30th when he will be in superior conjunction with the Sun, and then becomes an evening Star. He will be at greatest elongation West on the 5th rising in Gemini about eight degrees due South of Pollux an hour and ten minutes before the Sun, and will be visible during the first half of the month.

Venus—Is an evening Star increasing her altitude above the Sun, and setting nearly three hours after the Sun throughout the month.

Mars—Is also an evening Star in conjunction with Venus on the 6th when the two planets will be within ten minutes of arc of each other. Mars sets nearly three hours after the Sun at the beginning of the month, and two after at its close. Position on the 15th R.A. 12·2, Dec. 0° 16′ North, in Virgo.

Jupiter—is a morning Star until the 11th when he will be in opposition to the Sun, and on the meridian at midnight ; and

then becomes an evening Star for the rest of the year. Position on the 15th R.A. 21·32, Dec. 15° 32′ South.

Saturn—is a morning Star rising in Taurus about three hours before the Sun on the 1st and about four and a half hours before on the 31st. Position on the 15th R.A. 5·56, Dec. 22° 19′ North.

Uranus—In Capricornus will be in opposition to the Sun on the 3rd. Position on the 15th R.A. 20·47, Dec. 18° 37′ South.

Neptune—In Cancer. Position on the 15th R.A. 8·3, Dec. 20° 1′ North.

The Sun.

There will be a total eclipse of the Sun on the 21st, but it will be only partial in India, and very little will be seen of it in this country, as it will only commence about forty minutes before sunset.

For the month of September 1914.

Sidereal time at 8 p. m.

	H.	N.	S.
September 1st	18	39	37
,, *8th*	19	7	13
,, *15th*	19	34	49
,, *22nd*	20	2	25
,, *29th*	20	30	1

From this table the constellations visible during the evenings in September can be ascertained by a reference to a Star chart, as the above hours of sidereal time represent the hours of Right Ascension on the meridian.

Phases of the Moon.

September 4th Full Moon	7 31	P.M.
,, *12th* Last Quarter	11 18	,,
,, *19th* New Moon	3 3	A.M.
,, *27th* First Quarter ..	5 33	P.M.

There will be a partial eclipse of the moon on the 4th, commencing at 4-49 P.M., middle contract being at 6-28 P.M. and final contract at 8-8 P.M.

Meteors.

	Radiant. R. A.	Dec.	Character.
August—September ...	346°	+ 1°	Slow.
September 3rd—21st ...	60°	+49°	
,, *6th—15th* ...	62°	+36°	Swift; streaks.
,, *6th—17th* ...	106°	+52°	,,
,, *12th—22nd* ...	74°	+41°	
,, *27th* ...	4°	+28°	Slow.

The Planets.

Mercury—Is an evening Star throughout the month, setting very soon after the Sun on the 1st and an hour and a quarter after on the 30th.

Venus—Also is an evening Star, setting nearly three hours after the Sun all through the month. She will be at greatest elongation East on the 18th, being then more than 46 degrees above the Sun.

Mars—Also is an evening Star, but approaching conjunction with the Sun, which will occur in December, his altitude decreases. He sets two hours after the Sun on the 1st and about an hour and a half after on the 30th. Position on the 15th R.A. 13·16, December 7° 52′ South.

Jupiter—Also is an evening Star, still in Capricornus. Position on the 15th R.A. 21·4, Dec. 17° 47′ South.

Saturn—Is a morning Star, rising in Gemini four and a half hours before the Sun on the 1st and more than six hours before on the 30th. Position on the 15th. R. A. 6·6, Dec. 22° 17′ North.

Uranus—In Capricornus. Position on the 15th R.A. 20·42, Dec. 18° 52′ South.

Neptune—In Cancer. Position on the 15th R.A. 8·7, Dec. 19° 49′ North.

For the month of October 1914.

Sidereal time at 8 p.m.

		H.	M.	S.
October	*1st*	20	37	54
,,	*8th*	21	5	30
,,	*15th*	21	33	6
,,	*22nd*	22	0	41
,,	*29th*	22	28	17

From this table the constellations visible during the evenings in October can be ascertained by a reference to a Star chart, as the above hours of sidereal time represent the hours of Right Ascension on the meridian.

Phases of the Moon.

October	*4th*	Full Moon	11 29	A.M.
,,	*12th*	Last Quarter	3 3	P.M.
,,	*19th*	New Moon	0 3	P.M.
,,	*26th*	First Quarter	4 14	A.M.

Meteors.

		Radiant. R.A.	Dec.	Character.
October	*2nd* ...	230°	+ 52°	Slow; bright.
,,	*8th—16th* ...	44°	+ 58°	Small; short.
,,	*15th—24th* ...	92°	+ 15°	Swift; streaks; brilliant.
,,	*22nd—27th* ...	100°	+ 13°	Swift; streaks.
,,	*29th—Nov. 1st* ...	43°	+ 22°	Slow; bright.

The Planets.

Mercury—Is an evening Star throughout the month and attains his maximum altitude above the Sun on the 15th, when he is at greatest elongation East 24° 52′. Setting about an hour after the Sun, he will be visible all through the month.

Venus—Also is an evening Star, and will be at her greatest brilliancy on the 23rd. She sets about three hours after the

Sun on the 1st and a little more than two hours after on the 31st.

Mars—Also is an evening Star, setting an hour and a half after the Sun at the beginning of the month, and an hour after at the close. He will be close to Mercury throughout the month. Position on the 15th R.A. 14·34, Dec. 15° 13′ South, in Libra.

Jupiter—Also is an evening Star, still in Capricornus. Position on the 15th R.A. 21·1, Dec. 18° 0′ South.

Saturn—A morning Star, rises in Gemini from six and a half hours to eight hours before the Sun as the month advances. position on the 15th R.A. 6·10, Dec. 22° 16′ North.

Uranus—In Capricornus. Position on the 15th R.A. 20·41, Dec. 18° 59′ South.

Neptune—In Cancer. Position on the 15th R.A. 8·9, Dec. 19° 42′ North.

For the month of November 1914.

Sidereal time at 8 p.m.

		H.	M.	S.
November	*1st*	22	40	7
,,	*8th*	23	7	43
,,	*15th*	23	35	19
,,	*22nd*	0	2	55
,,	*29th*	0	30	30

From this table the constellations visible during the evenings in November can be ascertained by a reference to a Star chart, as the above hours of sidereal time represent the hours of Right Ascension on the meridian.

Phases of the Moon.

November	*2nd*	Full Moon.	5	19	A.M.
,,	*11th*	Last Quarter	5	7	,,
,,	*17th*	New Moon	9	32	P.M.
,,	*25th*	First Quarter	7	9	,,

Meteors.

	Radiant. R.A.	Dec.	Character.
October 29th—November 1st	43°	+ 22°	Slow ; bright.
November 13th—16th	151°	+ 22°	Swift ; streaks ; brilliant.
,, *13th—28th*	154°	+ 40°	Swift ; Streaks.
,, *17th—23rd*	25°	+ 44°	Very slow ; trains ; brilliant.
,, *19th—23rd*	63°	+ 22°	Slow ; bright.
,, *23rd—30th*	189°	+ 73°	Rather swift.

The Planets.

Mercury—Is an evening Star until the 7th when he will be in inferior conjunction with the Sun, and will transit the Sun's disc. The internal contact at ingress will occur at 3-30 P.M., and the planet will be on the meridian of the Sun at 5-33 P.M. The internal contact at egress will take place after sunset, at 7-37 P.M. The last transit happened in May 1907, and the phenomenon will not occur again until May 1924.

Venus—Is an evening Star until the 27th when she will be in inferior conjunction with the Sun. She sets about two hours after the Sun at the beginning of the month, and with the Sun on the 27th.

Mars—Also is an evening Star, but his altitude diminishes daily as conjunction with the Sun which occurs on December 24th draws nearer. He sets an hour after the Sun on the 1st and twenty-seven minutes after on the 30th. Position on the 15th R.A. 16·3, Dec. 9° 21′ South, in Scorpio.

Jupiter—Also is an evening Star in Capricornus. He will be in quadrature on the 7th. Position on the 15th R.A. 21·9, Dec. 17° 20′ South.

Saturn—In Gemini, is a morning Star rising soon after 9 P.M. at the middle of the month. Position on the 15th R.A. 6·6, Dec. 22° 16′ North. He has been retrograding since October 15th.

Uranus—In Capricornus. Position on the 15th R.A. 20·42, Dec. 18° 53′ South.

Neptune—In Cancer. Position on the 15th R.A. 8·10, Dec. 19° 42′ North.

Notices of the Society.

Election of Members.

THE attention of members is invited to Bye-Law No. 14, regulating the election of persons who desire to join the Society. It is hoped that those who are already members will induce others to join. Forms of application can be had from the Secretary.

Change of Addresses.

It is particularly requested that when members change their addresses, they will kindly notify the new address to the Secretary. The omission to do this is likely to cause the loss of the JOURNALS and other communications.

Telegraphic Address.

The address of the Society has been registered at the Telegraph Office, Calcutta. Telegrams should be addressed "Astronomy", Calcutta.

The Library.

Suggestions as to useful books for the Library will be welcomed by the Librarian. The books available can be ascertained from the Assistant Librarian and can be borrowed by members in accordance with the Bye-Laws. The reading-room of the Society in the Imperial Secretariat is now opened for the use of members from 5 to 7 P.M., on Mondays.

Subscriptions.

Subscriptions for the current session fell due on 1st October 1913. Those who have not paid in their subscriptions are requested to remit them to the Treasurer without delay.

Addresses of Officers.

	To
Money Orders or letters containing money or cheques should be addressed.	RAI BAHADUR U. L. BANERJEE, Office of the Accountant-General, Bengal, 3, Koila Ghat Street, Calcutta.

All other communications ... { (*Name*) D. N. DUTT, ESQ. (*Designation*) Business Secretary of the Astronomical Society of India, Imperial Secretariat (Treasury) Buildings, Calcutta.

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